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RETROGRADE PELVIC VENOGRAPHY

by

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A number of different methods have been suggested for the roentgen examination of the iliac veins. DRASNAR (1943) injected contrast medium into a bone of the pelvis. Venography with injection of contrast medium into the dorsal vein of the penis was described by DE LA PEÑA (1946). GUILHEM & BAUX have shown that it was possible to secure filling of veins passing from the uterus by injection into the uterus itself. With these methods of examination there is usually contrast filling only of the veins passing from the injection site; the large central veins of the pelvis show incomplete filling, partly because the flow of contrast medium and the blood stream in the large vessels sometimes run parallel and are not admixed (KJELLBERG).

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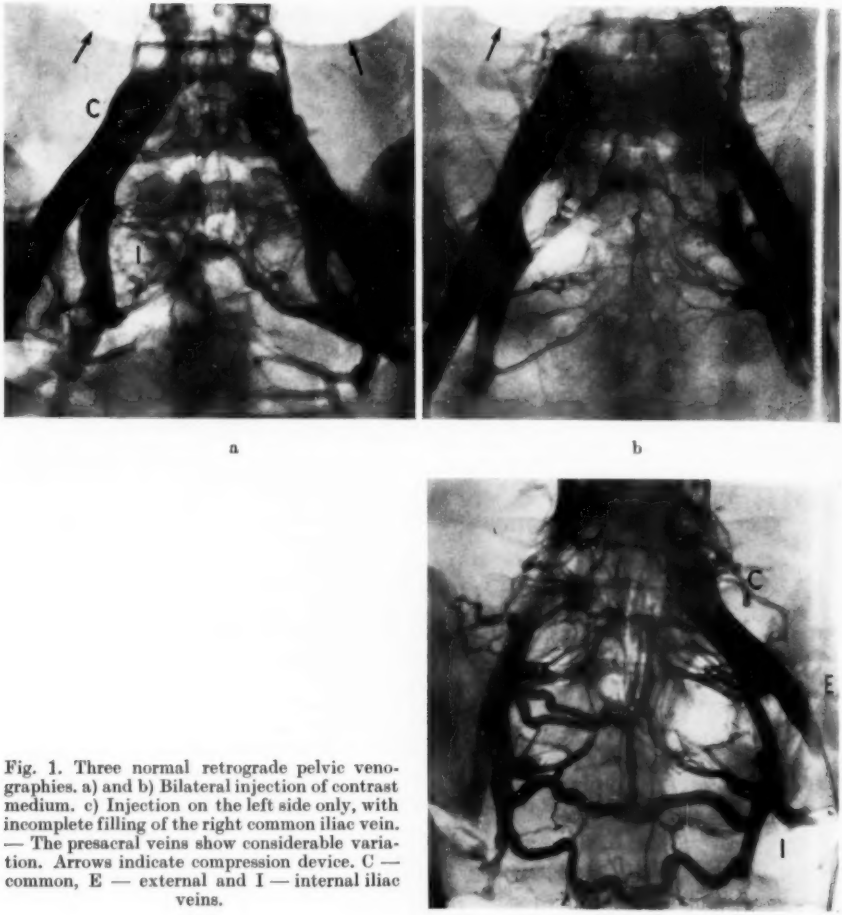

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Fig. 1. Three normal retrograde pelvic venographies. a) and b) Bilateral injection of contrast medium. c) Injection on the left side only, with incomplete filling of the right common iliac vein. — The presacral veins show considerable variation. Arrows indicate compression device. C — common, E — external and I — internal iliac veins.

FARIÑAS (1947) described a method of examining the large pelvic veins in which the contrast medium was injected into the saphenous vein on each side. He also pointed out that filling of those veins could be improved by compressing the inferior vena cava with a rubber balloon. A similar method, with injection of the medium through puncture needles in both femoral veins and compression of the inferior vena cava with a rubber balloon, was reported in 1954 by DALALI, PLENTL & BACHMAN.

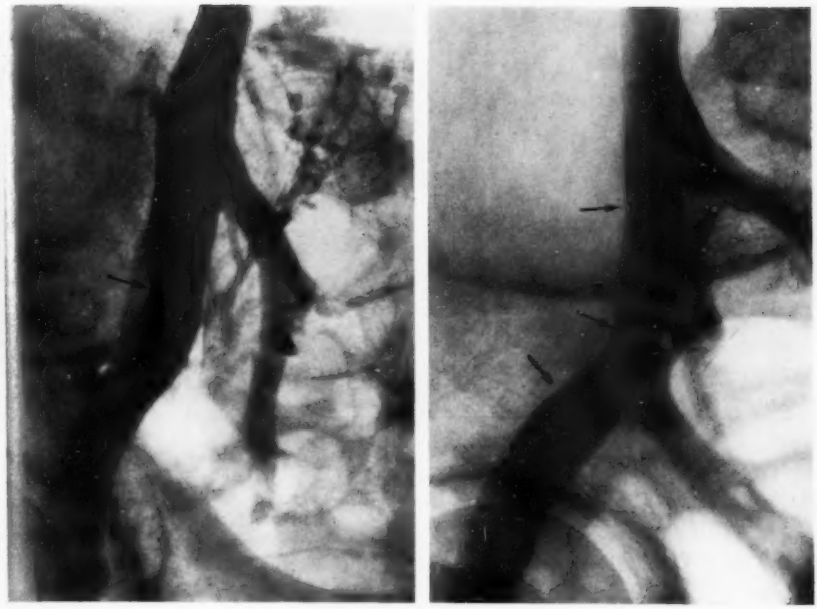

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Fig. 2. The right external iliac vein is somewhat compressed from the front by the distended external iliac artery. a) a. p. and b) oblique projections.

Their purpose was to study problems associated with cancer of the female genital tract. Forty patients were examined. In their opinion, 'venographic studies of the pelvis may be of considerable significance in the prognosis and therapy of patients with cancer of the female genital tract'.

Since 1954 we have employed a method similar to the last-named for contrast examination of the large veins of the pelvis. The principal features of the technique were reported in 1955 (HELANDER & LINDBOM). Our aim was, with the cooperation of KOTTMEIER, to improve the diagnosis of uterine carcinoma metastases in the pelvic walls. We have now employed the method for more than three years in a large number of cases, and hence feel justified in communicating our findings.

BARTLEY (1958), using a somewhat similar technique, described the angiographic appearances of the iliac veins and the changes in cases of pelvic tumour.

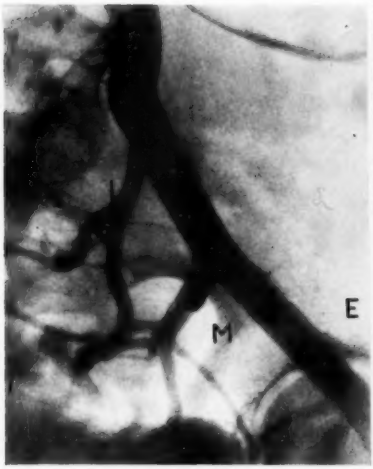


Fig. 3. Common anatomical variation. Internal (I) and middle (M) iliac veins. Oblique view.

Fig. 4. Uncommon anatomical variation of internal iliac and presacral veins.

Technique

The femoral vein on each side was punctured in a proximal direction and polythene catheters (No. 205) inserted, the tip of each being advanced to a point about 11 cm from the site of puncture in the skin. The extremity was then usually situated in the external iliac vein approximately at its union with the internal iliac vein into which the injection could accordingly be made. Using a compression belt and a wooden block or a football bladder, the inferior vena cava was then compressed at the level, and slightly to the right of the umbilicus, sufficient pressure being applied to occlude the vein; palpation of the femoral artery ensured that the aorta had not been compressed. Effective compression was sometimes impracticable in obese patients, but it was accomplished in about 95 per cent of cases. Immediately compression had been applied, 30 ml of the contrast medium were injected simultaneously through each catheter into the external iliac vein at the rate of about 8 ml per second, a total dose of 60 ml in about 4 seconds. The first roentgenogram was taken on completion of the injection and a further two or three films at intervals of 3 to 5 seconds thereafter. Satisfactory demonstration of the pelvic veins was obtained by tilting the tube so that the beam was directed towards the head at an angle of about 10 degrees from the vertical (Fig. 1). Sometimes another series of roentgenograms was taken in the oblique projection, also during compression of the vena cava, with

contrast medium injected only on the side that was rotated downwards (Figs. 3 and 5). While trying out the method, we examined a few patients both supine and prone and in an almost vertical position. We found that with a 30 per cent contrast medium, contrast filling of the veins occurred in the same way and to the same extent in different body postures. Subsequently we invariably performed these examinations with the patients supine. In the most recent cases the contrast medium was injected with GIDLUND's pressure syringe fitted with a branched tube. The injection can be made equally well with a conventional syringe on both sides, although it will then require two operators.

If puncture failed on one side, perhaps due to obliteration of the vein or radiation edema in the groin, fairly satisfactory bilateral filling of the large pelvic veins could still be secured by unilateral contrast injection. The contralateral external and common iliac veins then, however, filled incompletely (Fig. 1 c). On unilateral injection the internal iliac vein on each side usually showed contrast filling; but since this was not always the case, bilateral injection is required for evaluating any deformation of the vessel which may be present.

We also tried retrograde contrast filling of the internal iliac vein with the injection given directly therein through a curved catheter inserted percutaneously during screening. The method was, however, too time-consuming for use in routine examinations.

A total of 304 patients of from 14 to 73 years of age were examined by the present method. Only a few of them were of reproductive age. The sex distribution was 285 females and 19 males, and 227 of the former had uterine carcinoma.

Complications. We have employed this method of bilateral venous catheterization also for the investigation of the inferior vena cava, and so far in a total of 650 cases. One serious complication occurred in this series. An obese woman, 59 years of age with Stage III carcinoma of the cervix died seven days after the pelvic venography. Autopsy disclosed pulmonary emboli and residue of thrombi in the femoral and iliac veins bilaterally. Due to a number of unfortunate circumstances, this patient had remained completely immobile in bed for a whole week after the examination, and quite likely the venous catheterization was a major cause of the thrombosis. Since this incident, care has been taken to ensure that all patients are up and about directly after the examination, and no further cases of thrombosis have been diagnosed. In view of the danger of thrombosis, retrograde pelvic venography should not be undertaken during the last few days preceding an operation. Since the majority of our patients had uterine carcinoma and anticoagulants were deemed to be contraindicated, due to the danger of hemorrhage, such agents were administered only exceptionally in connection with the examination.

Fig. 5. Oblique view showing usual position of valves in main branches of right internal iliac vein. Veins distended by contrast medium and valves (arrows) closed.

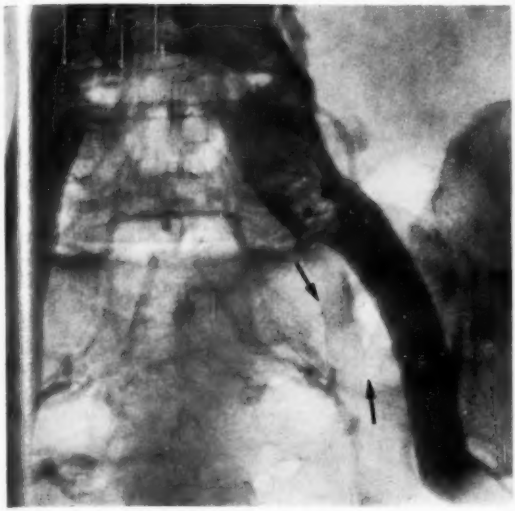
Fig. 6. Valves situated more cranially than usual in the right internal iliac vein, in the left at the ordinary level.

Fig. 6

In a few cases in which the femoral artery was punctured by mistake, hematomas arose in the groin but usually produced only slight, transient symptoms.

Anatomy

In nearly all cases that were examined the external iliac vein was present bilaterally. In a few instances where the venipuncture could not be made satisfactorily, it was felt that the vein was probably obliterated or absent. The external iliac artery passes anterior to the corresponding vein, and in some patients past the age of 50, deformation of the external iliac vein due to compression from the dilated artery was demonstrable (Fig. 2). In about 70 per cent of the cases the internal iliac vein consisted of a single venous trunk on either side (Fig. 1). In approximately 20 per cent two vessels (the internal and middle iliac veins) were discernible on at least one side (Fig. 3). In approximately 10 per cent the internal iliac vein had either the character of a venous network, emptied high up into the common iliac vein at the promontory, or showed other



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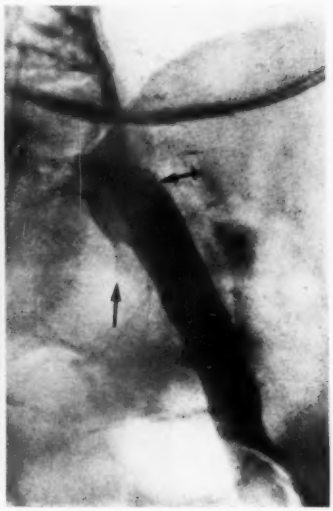

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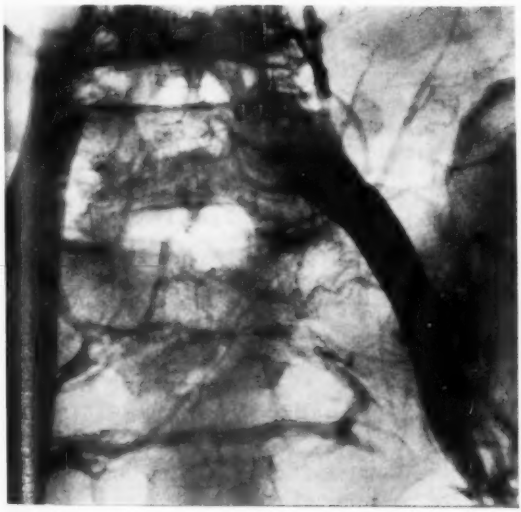

c

Fig. 7.

Recent thrombus in the left internal iliac vein, showing contrast medium penetrating between the former and the vessel wall (↑).

a) A. p.

b) Oblique. The head of the thrombus is discernible as a filling defect in the common iliac vein (‡).

c) Two months later. The internal iliac vein is now completely obliterated and the thrombus head has disappeared.

Fig. 8. Condition following thrombosis of iliac veins on left side. Recanalization of common and external iliac veins but not of internal iliac vein. The recanalized veins (‡) are narrower than those of the other side, which have not been thrombosed; they have a somewhat irregular lumen with long filling defects (†).

variations (Fig. 4). The left common iliac vein was often compressed in its cranial portion and hence could not be evaluated (Fig. 1); the contralateral one invariably showed contrast filling and no anatomical variations worthy of note.

The cranial parts of the common iliac vein and the caudal end of the inferior vena cava at the promontory can be examined only during the injection of contrast medium without inferior vena cava compression, and not by the method reported here.

During the injection, when the flow through the inferior vena cava was obstructed, the contents of the common and external iliac veins on both sides increased rapidly. These vessels dilated, whereupon the valves in the cranial part of the femoral vein closed, and the contrast medium was forced in a retrograde fashion to fill both internal iliac veins. From here it passed through the presacral into the sacral veins, then up via the lumbar veins to the azygos veins (HELANDER & LINDBOM). In about one-half of the cases, valves were evident in the internal iliac vein or its branches. Their sites somewhat varied; they were usually about 5 cm from the junction of the external iliac vein, which in relation to the

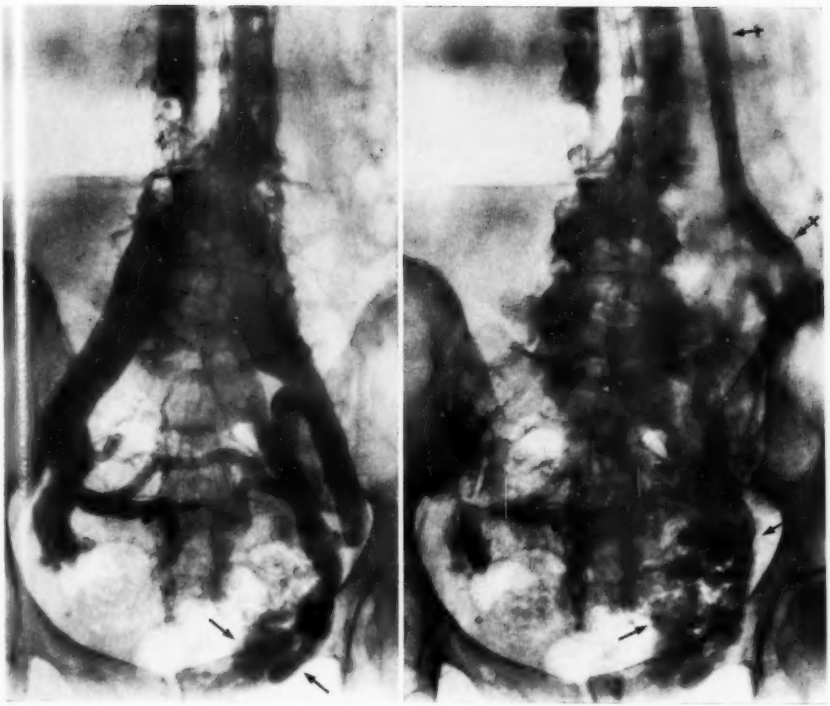

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Fig. 9. Contrast filling of the uterovaginal and vesical plexuses on the left side (↑). These veins are distended, and the contrast medium has passed into the abnormally wide left ovarian vein (‡). Varicocele of the broad ligament. a) During injection, b) a few seconds later.

pelvis corresponds to a point approximately 2 cm cranial to and behind the ischial spine (Fig. 5). In approximately a further one-third of our cases the contrast medium was halted at the same level and, although no valves were obvious in the roentgenograms, they were nevertheless assumed to be present. Functioning valves in the internal iliac vein or its branches were thus likely to have been present in about 85 per cent of the cases; in virtually all cases the valves were situated at the same level bilaterally. In one of the 304 cases, however, there were valves in the right internal iliac vein only 2 cm from the common iliac vein whereas those on the left side lay in the usual situation (Fig. 6). (Contrast filling of venous plexuses in the pelvis and of the ovarian vein are dealt with later.)

Pathologic findings

Thrombi. Recent thrombi in veins of the pelvis were found in four cases. In these the contrast medium had penetrated between the vascular wall and the, as yet, non-adherent thrombus. In two of them, an internal iliac vein was completely thrombosed; in one of these two cases there was projection of the head of a thrombus into the common iliac vein (Fig. 7). In one case of advanced ovarian carcinoma with edema of the left leg, a non-adherent thrombus occupied the whole of the external and common iliac veins on that side. In one case with contrast filling of the uterovaginal plexus a filling defect in a vein passing from the plexus was observed in two different projections — probably a recent thrombus.

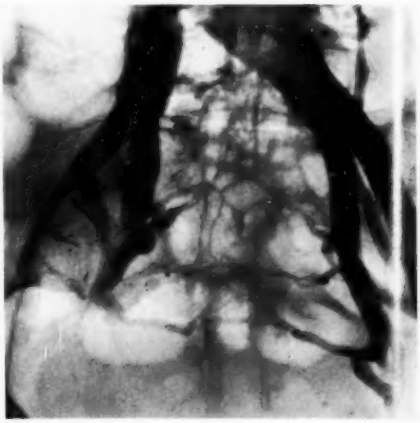

Fig. 10. Carcinoma of the cervix. Deformation of the right external iliac vein which is displaced anteriorly and laterally (arrows) by operatively verified metastases situated behind and medial to the vessel.

Post-thrombotic deformation of the external iliac vein was evident in four cases. The recanalized vein had a somewhat irregular lumen that was narrower than the contralateral one, and showed filling defects parallel with the wall (Fig. 8).

Venectasia. Peripheral veins showed retrograde contrast filling in approximately one-third of all cases examined. In 46 cases there was more or less complete filling of the uterovaginal plexus on one side or bilaterally, nearly always from the internal iliac vein (Fig. 9). In 37 cases, the vesical plexus filled on one or both sides, usually via the internal pudendal vein. Gluteal veins showed contrast filling, although only partial, in a few cases. The valves in the gluteal veins are probably seldom incompetent.

The peripheral contrast-filled veins often appeared to be abnormally wide. Twenty-six cases showed filling of the left ovarian vein; in most of these cases the ovarian vein served as the principal outflow channel from the pelvis during occlusion of the inferior vena cava. In 16 of these 26 cases the veins of the uterus and the ovarian region were so wide (0.5 to 1 cm) that the condition could be described as varicocele of the broad ligament (Fig. 9). In the gynecologic literature this is regarded as a controversial state which may give rise to pain which is only present

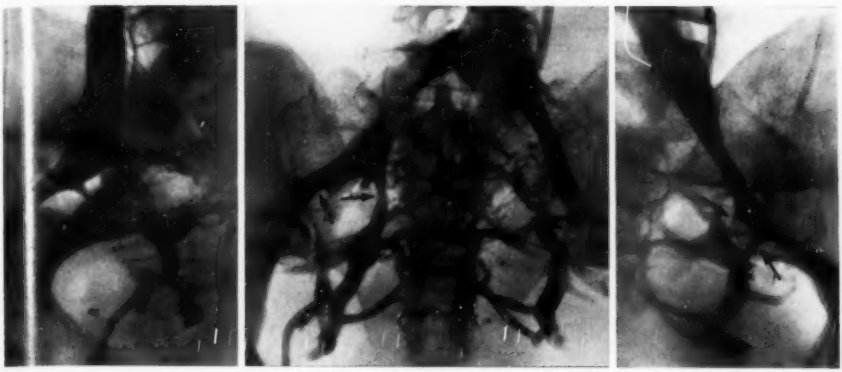

Fig. 11. Gross deformities of the veins of the pelvis in a case of advanced carcinoma of the cervix. Both internal iliac veins show indentations close to their junctions with the corresponding external iliac veins (↑). The right external iliac vein is displaced forwards and laterally (‡). There is also deformation of the left external iliac vein which is compressed from in front, though to such degree that it can scarcely be attributed solely to a distended iliac artery.

when the subject is out of bed and about. The pain, it is said, may subside after operation. The etiology of this condition is unknown, and the diagnosis is reported to be difficult or impossible to establish before operation; by the method described, the diagnosis may be made without laparotomy.

The reason why peripheral veins were contrast filled in some of our cases is obscure. We found no evidence to show whether it was due to the absence or incompetence of the valves. Retrograde filling of the vesical plexus occurred only in about 10 per cent of the patients examined, and hence too seldom for use as a diagnostic aid.

Deformation by tumours. Deformation of the iliac veins associated with expansive processes in the true pelvis was observed in about 50 cases. The majority of these had metastases from carcinoma of the cervix in lymph glands along the pelvic walls. The lymph stream from the uterus passes largely to the internal iliac (hypogastric) glands and the external iliac glands along the corresponding veins. Frequently there is a group of glands in the region of the union of the internal and external iliac veins. When these glands are enlarged, they may produce indentations in the venous wall, and hence there is a fair chance of demonstrating venous deformities, due to glandular metastases, particularly when the veins are distended by contrast medium, as in the present method of examination. In these cases the vessel was usually compressed from one side, though in advanced cases where tumour tissue surrounded it, the

Fig. 12

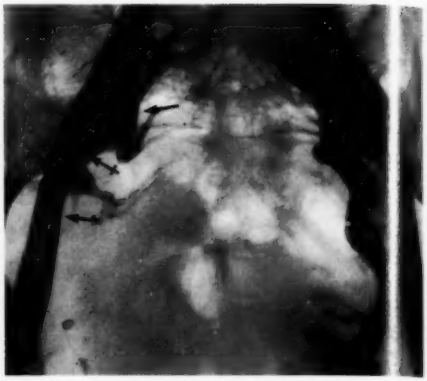

Fig. 13. Large metastases from carcinoma of the cervix along the right pelvic wall. Only a small stump of the internal iliac vein contrast-filled (↑). Medial indentation (‡) of the external iliac vein. Left side normal.

Fig. 12. Deformities and obliterations of the large pelvic veins in a case of advanced carcinoma of the cervix with spread along both pelvic walls. Left internal and common iliac veins obliterated. Left ascending lumbar vein distended draining blood from left external iliac vein (↑). Right external iliac vein is indented and internal iliac vein (double) displaced by the tumour (‡).

walls sometimes showed inward bulges on either side. Displacement of veins was not common, unless there was concurrent narrowing.

The external iliac vein was generally indented from the medial side or from medially and behind, often just anterior to the junction with the internal iliac vein (Fig. 10). A long and regular impression in the external iliac vein from in front was usually caused by a dilated iliac artery (Fig. 2). The internal iliac vein was in some cases indented at or near its junction with the external iliac vein (Fig. 11), and in a few cases was completely obliterated (Fig. 12). In such cases of total obliteration it is usually impossible to ascertain if the vessel is compressed and/or thrombosed. Those uncommon cases in which valves are present high up in the internal iliac vein may be distinguished in a typical roentgenogram of closed valves (Fig. 6). In some cases contrast filling of the internal iliac vein differed in level on the two sides (Fig. 13). When no valve was observed at the obstruction and there was no filling defect pointing to a thrombus, the explanation lay in compression of the vein by a tumour. Due to the above-mentioned accumulation of lymph glands about the

junction of the external and internal iliac veins, the possibilities of demonstrating deformities are probably best in that region. Compression of the internal iliac vein concomitant with deformation of the external iliac vein was regarded as a definite sign of tumour (Fig. 13). In a few cases of advanced tumours, gross deformities and obliterations of the large veins of the pelvis were observed (Fig. 12).

The venographic findings in our tumour cases were confirmed by various means. In 19 cases, both positive and negative findings were verified at subsequent operations. Urographic examinations were also performed in all venographies and in some cases compression of a ureter was demonstrated at approximately the same site as a venous indentation. This suggested that the deformation of the vein had been correctly evaluated.

SUMMARY

Retrograde pelvic venography enables the iliac veins to be examined in a distended state. Expansive processes in the pelvis, especially lymph gland metastases along the pelvic walls, may be demonstrated and localized. Post-thrombotic deformities of the iliac veins, recent thrombi, and varicoceles of the broad ligaments may also be diagnosed by the method.

ZUSAMMENFASSUNG

Die retrograde Beckenvenographie ermöglicht es, die iliakalen Venen im gefüllten Zustand zu untersuchen. Expansive Prozesse im Becken, besonders Lymphdrüsenmetastasen längs der Beckenwände, können demonstriert und lokalisiert werden. Post-thrombotische Deformierungen der iliakalen Venen, beginnende Thrombosen und Varikozelen der Plica lata können ebenfalls mit dieser Methode diagnostiziert werden.

RÉSUMÉ

La phlébographie pelvienne rétrograde permet d'examiner les veines iliaques en état de distension. Elle permet de mettre en évidence et de localiser les tumeurs intrapelviennes, en particulier les métastases ganglionnaires lymphatiques le long des parois pelviennes. Les déformations post-thrombotiques des veines iliaques, les thrombus récents et les varicocèles des ligaments larges peuvent aussi être diagnostiqués par cette méthode.

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INFUNDIBULAR WIDENING OF THE POSTERIOR COMMUNICATING ARTERY STUDIED BY CAROTID ANGIOGRAPHY

by

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According to earlier reports, the posterior communicating artery, and through it the posterior cerebral artery, become filled with contrast medium in one-third to one-fifth of all carotid angiographies. A closer study of cases showing filling of the posterior communicating artery reveals that this vessel is often funnel-shaped at the site where it leaves the carotid siphon. This funnel-shaped part (see Fig. 1), called the infundibulum in the present paper, may vary considerably in size and shape. When the posterior communicating artery is as wide, or nearly as wide, as the posterior cerebral artery the contrast density is much the same in the infundibulum as in other parts of the lumen. When the greater part of the posterior communicating artery is narrow, and particularly if it is much narrower than the posterior cerebral artery, the contrast density is often much greater in the infundibular part than in other parts of the vessel (Fig. 1). Oblique views may, if necessary, be used to dispel all doubts as to the anatomic continuity between the wider infundibular part and the narrower continuation of the posterior communicating artery.

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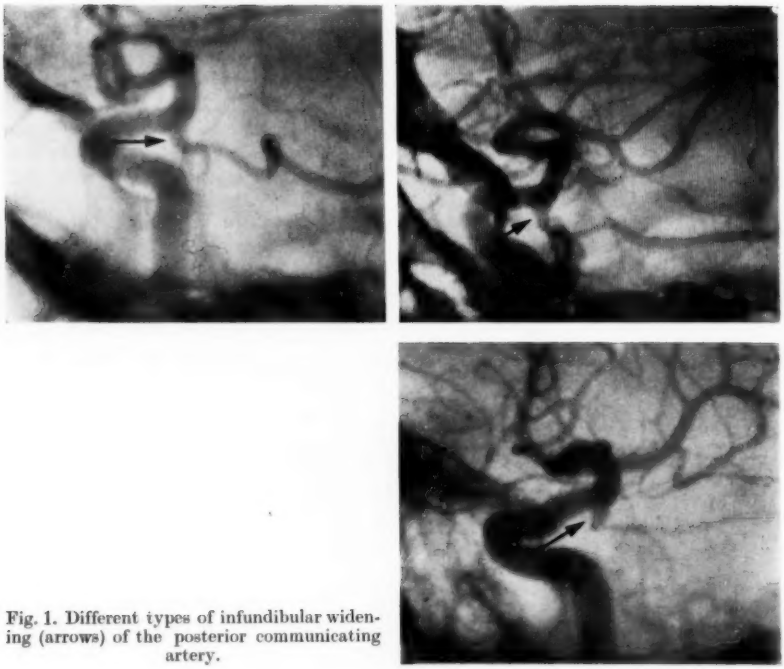


Fig. 1. Different types of infundibular widening (arrows) of the posterior communicating artery.

In some cases in which the posterior communicating artery has not been filled, a broad-based bulging in the wall of the carotid siphon, of varying size and shape, may be seen at the site where the former artery arises. This formation and its variations are shown in Fig. 2.

A survey of a normal material (angiographies without evidence of other vascular lesions) of 1 020 patients revealed a bulging in the vessel wall in 67 instances, *i. e.* 6.6 $\pm$ 0.8 %. Approximately the same incidence was established in a material comprising 223 cases of intracranial expansive processes and among 118 cases of arterial aneurysm in the carotid region. The figure corresponds to 10.1 $\pm$ 1.2 % of the carotid angiographies in which the posterior cerebral artery was not demonstrated. This bulging was not observed in a single case in which the posterior communicating artery was shown. The appearance of the bulge in many cases corresponded completely with the infundibulum of the posterior communicating artery (cf. Figs. 1 and 2). In two cases, bulging in the carotid siphon was visible on both sides.

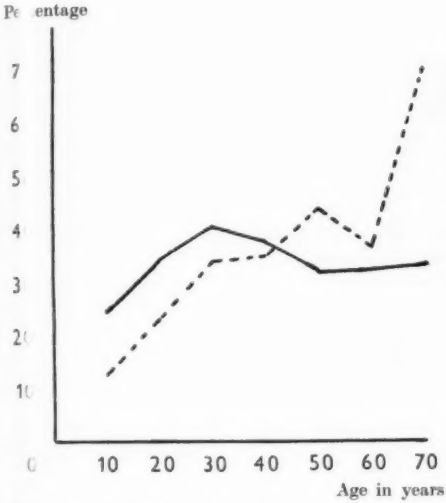


Diagram showing incidence of contrast filling in the posterior cerebral artery (solid line) and the infundibulum of the posterior communicating artery (broken line). In the latter curve all values have been multiplied by 5.28 in order to bring the two curves to the same level.

When studying the aforementioned material, I encountered several cases in which a number of angiographies had been carried out in the same region. Among these, a few showed filling of the posterior cerebral artery at one examination while at another a bulging at the point of origin of the posterior communicating artery was seen. The bulge corresponded exactly with the infundibulum of the posterior communicating artery, as exemplified in Figs. 3 to 5.

In an analysis of 265 rapid serial angiographies of the carotid artery (SJÖGREN & FREDZELL, GREITZ) I noted that the posterior communicating and posterior cerebral arteries were sometimes filled in only one or a few views taken in the arterial phase. This finding, which has been discussed in more detail in another connection, made it possible in a few cases to study at one and the same injection the infundibulum of the posterior communicating artery both when it alone was filled and when it was demonstrated together with other parts of the vessel (Figs. 6 and 7). These observations gave added support to the view that the above-mentioned bulging in the carotid siphon is identical with the infundibulum of the posterior communicating artery.

Compression of the vertebral artery may be used to ascertain with certainty whether a bulging in the carotid siphon corresponds with the infundibulum of the posterior communicating artery as described in an earlier article (ref. 3, Fig. 1). This method may, if necessary, be combined with oblique projections. It is still too early to state how effectively a non-filled posterior communicating artery may be demonstrated by vertebral artery compression.

The incidence of isolated filling of the infundibular part of the posterior communicating artery becomes greater with increasing age, as may be seen from the diagram above in which the curve representing isolated filling may be compared with the corresponding curve for filling of the posterior cerebral artery in carotid angiographies. The curves display

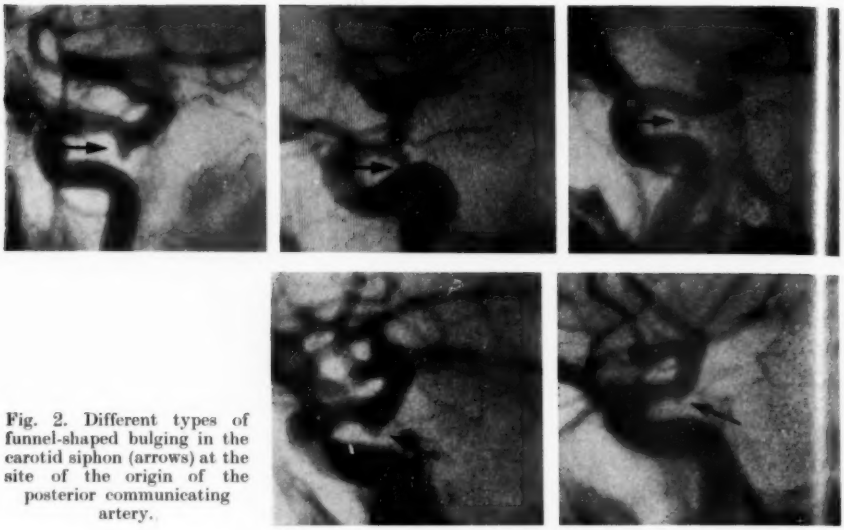


Fig. 2. Different types of funnel-shaped bulging in the carotid siphon (arrows) at the site of the origin of the posterior communicating artery.

noticeable differences. In order to avoid statistical errors due to unusually small numbers I also compared the incidence in only 2 groups, namely, in patients under and over 40 years of age. The infundibulum filled in 26 out of 517 patients under 40 (5.0 %), while for those over 40 the corresponding figures were 41 out of 503 (8.2 %). This difference is statistically almost significant. (By almost significant is meant that the probability that the difference was due to chance was greater than 1 % and less than 5 %.) A comparison between men and women in our material showed isolated filling of the infundibulum of the posterior communicating artery 39 times among 531 men (7.3 %) and 28 times among 489 women (5.7 %). This difference is not statistically significant. Comparing the incidence of this finding on both sides, no difference was noted. For the right side, the figures were 32 out of 482 (6.6 %) and for the left, 35 out of 538 (6.5 %).

The differences noted in this material for isolated filling of the infundibulum of the posterior communicating artery in different age-groups suggested that it was not merely a question of an insignificant variant. In order to ascertain the connection with clinical signs, the hospital records were investigated for all patients displaying this angiographic feature. This study revealed that 16 patients had had subarachnoid haemorrhage, while other clinical signs showed great variation. Among the 16 cases with subarachnoid haemorrhage, 6 had an aneurysm in the carotid area on the opposite side while 2 had a blood pressure de-

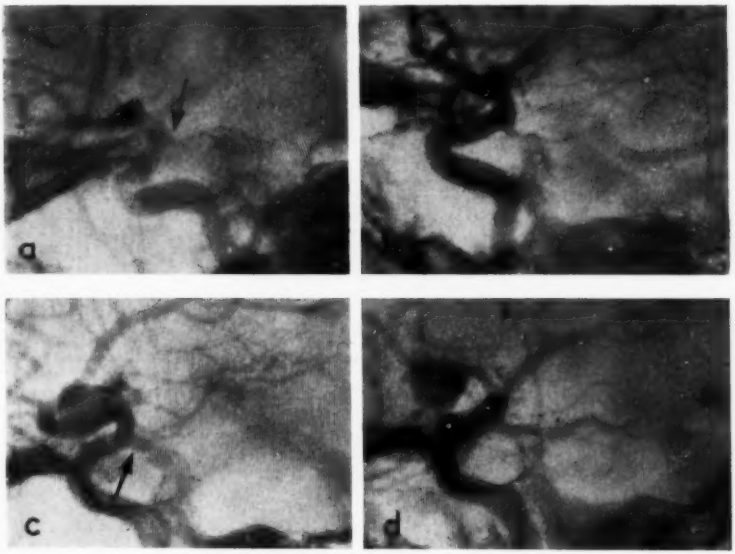


Fig. 3. Views obtained after separate injections into the same carotid artery. a) Only a funnel-shaped bulge (arrow) in the carotid siphon is filled. b) A narrow posterior communicating artery, obviously a continuation of the funnel-shaped bulge shown in (a), and a wider posterior cerebral artery. c) and d) Another case. c) A relatively long, funnel-shaped bulge (arrow) in the carotid siphon. d) The bulge corresponds with that part of the posterior communicating artery which is nearest the siphon. (Arterial aneurysm of the anterior cerebral artery.)

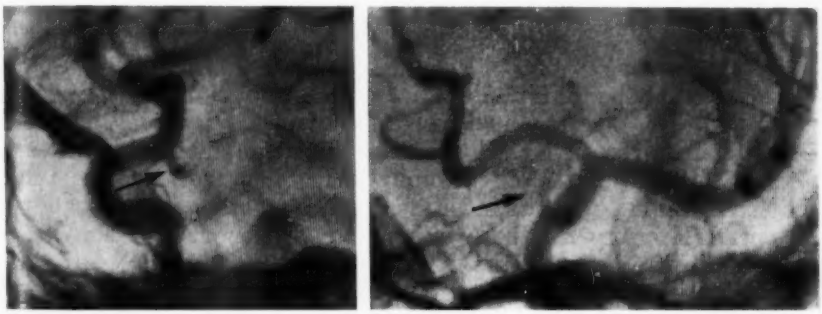
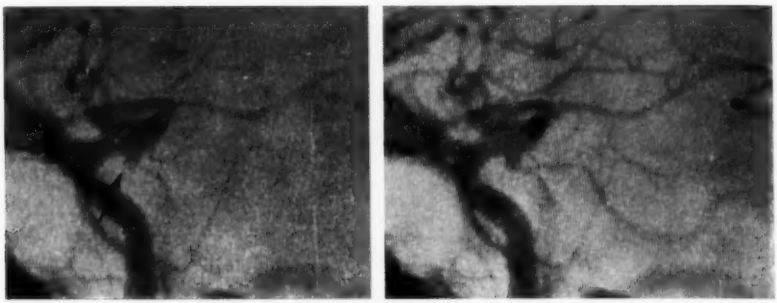
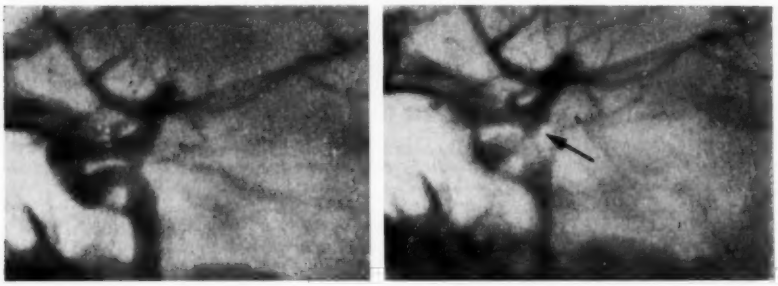


Fig. 4. Views obtained after different injections into the same carotid artery. a) A long bulge (arrow) in the carotid siphon at the origin of the posterior communicating artery. b) Oblique. Filling of a branch, in site and length corresponding with the posterior communicating artery (arrow).



a b

Fig. 5. Views from one and the same rapid serial angiography. a) Only the infundibular part (arrow) of the posterior communicating artery is filled while in (b) the whole of this vessel as well as the posterior cerebral artery are shown.



a b

Fig. 6. Views obtained from another rapid serial angiography. a) Both the posterior communicating artery, with a wide infundibulum, and the posterior cerebral artery are filled. b) Only the infundibular part (arrow) of the posterior communicating artery is visible.

tween 250 and 300 mm Hg. An explanation of the haemorrhage was thus at hand in these 8 cases. In the other 8, no explanation could be found; only one, however, had had a thorough angiographic examination. In 3 cases, only one carotid angiography had been performed, while in 4, this examination had been made on both sides but no angiography of the vertebral artery had been undertaken. Under such circumstances, the relationship between the infundibular widening of the posterior communicating artery and the subarachnoid haemorrhage is still open to question.

With the aim of investigating the histologic aspects of a possible connection between infundibular widening of the posterior communicating artery and subarachnoid haemorrhage, HASSLER and I have made a

p eliminary study of autopsy material from several cases with an unusually w de infundibular part of the posterior communicating artery. The v ssel wall displayed changes of varying degree, but in most instances t e resemblance to the wall in arterial aneurysm was striking. A more d tailed account of these vascular lesions is to be published in another c nnection.

SUMMARY

Infundibular widening of the posterior communicating artery has been studied in a la ge series of carotid angiographies. It is pointed out that the infundibular part of this v ssel not infrequently becomes filled with contrast medium without other parts of the v ssel being visible. The appearances in these cases are characteristic and are commonly en countered.

ZUSAMMENFASSUNG

Die infundibuläre Erweiterung der Arteria communicans posterior ist an einer grossen Serie von Karotisangiographien studiert worden. Es wird hervorgehoben, dass der infundibuläre Teil dieses Gefässes nicht selten vom Kontrastmittel ausgefüllt wird ohne dass andere Abschnitte des Gefässes sichtbar sind. Die Befunde in diesen Fällen sind charakteristisch und werden oft angetroffen.

RÉSUMÉ

L'auteur a étudié sur une grande série d'angiographies carotidiennes l'élargissement infundibulaire de l'artère communicante postérieure. Il insiste sur le fait que la partie infundibulaire de ce vaisseau est assez souvent remplie de moyen de contraste, sans que les autres parties de ce vaisseau soient rendues visibles. Dans ces cas, les images sont caractéristiques et se trouvent fréquemment.

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FROM THE INSTITUTE FOR CLINICAL AND EXPERIMENTAL SURGERY, PRAGUE, CZECHOSLOVAKIA

LYMPHOGRAPHY OF THE DEEP LYMPHATIC SYSTEM OF THE THIGH

by

P. Málek, J. Kolc and *A. Belán*

Lymphography of the extremities was made possible by KINMONTH who suggested the injection of contrast medium directly into a lymphatic vessel which had been marked by a dye and isolated (9, 10, 11). This method found recognition all over the world, but remained limited practically only to the superficial lymphatic system (1, 3, 4, 5, 7, 8). The only deep system which has been examined by lymphography is the one formed by the lymphatic vessels and nodes of the pelvic region (KINMONTH (11), BRUUN and ENGESET (2), COLLETTE (4)). Our experiences in experiments and in clinical practice suggest that both the superficial and the deep-seated systems as well as their mutual relationships must be investigated, as is now the usual procedure in the case of the blood vessels. A method, based upon anatomical studies, was therefore introduced which enabled us to demonstrate the deep lymphatic system of the popliteal region and of the thigh; in association with the now current method of KINMONTH, both the superficial and deep lymphatic systems may be examined simultaneously. Our method proved clinically satisfactory, the deep lymphatic system of the thigh always being demonstrable and occasional deviations well shown. A short account of the method and the results obtained is therefore presented.

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Fig. 1. Site of injection of the dye (1) and of the incision (2) for the isolation of the posterior superficial lymphatic vessel of the calf (3).

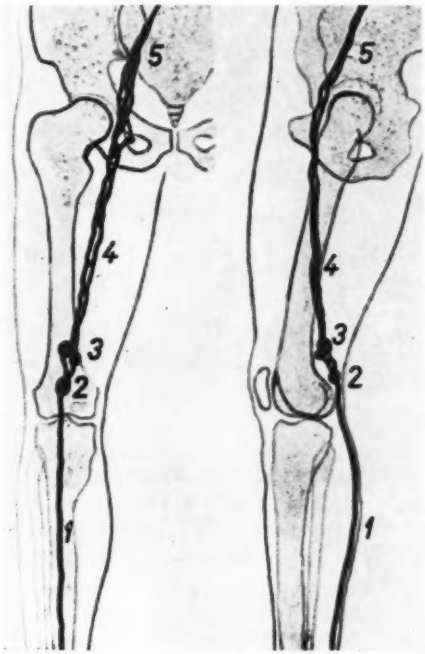

Fig. 2. Schematic presentation of the lymphatic vessels of the lower limb after injection of the posterior superficial lymphatic vessel of the calf.
1 — Superficial posterior lymphatic vessel of calf
2 — Superficial popliteal lymphatic node
3 — Deep popliteal lymphatic node
4 — Deep lymphatic vessels of thigh
5 — Lymphatic system of pelvis

It is known from the work of anatomists (JOSSIFOW, ZHDANOV) that the posterior group of superficial lymphatics of the calf, situated along the short saphenous vein, ends in the superficial popliteal node, from which the efferent lymphatic vessels run to the deep system of the thigh and along the femoral artery and external iliac artery to the pelvic region. It was assumed that should it prove possible to fill the posterior group of lymphatic vessels of the calf, this would constitute a method of demonstrating the deep system of the thigh. A convenient site for the application of the dye and the easy surgical accessibility and constant presence of a suitable lymphatic vessel were the factors sought in the development of the technique. We use the following procedure.

The dye (11 % patent blue in water) is injected into the outer side of the heel. An incision is then made behind and below the external malleolus (Fig. 1), where one or more lymphatic vessels running upwards and perhaps backwards from the heel are generally found; if several vessels are encountered, one running in this direction is chosen for the injection. The vessel is isolated and the contrast medium injected (Fig. 1). The injection is performed slowly since usually only a single vessel runs to the popliteal region (Fig. 2).

a b c

Fig. 3. Transition of two lymphatic vessels of the posterior superficial group of the calf to the system of popliteal nodes and to the deep system of the thigh. a) a.p. b) lateral c) oblique.

1 — Posterior superficial lymphatic vessels of calf
2 — Superficial popliteal lymphatic nodes
3 — Deep popliteal lymphatic nodes
4 — Deep lymphatic vessels of thigh

The lymphographic appearances are as follows. In the upper two thirds of the calf usually one (but occasionally two) lymphatic vessels may be seen proceeding medially to end in a superficial lymphatic node (Fig. 3 a). The system of deep-seated popliteal nodes is then filled; according to anatomists (JOSSIFOW, ZHDANOV) this system is variable as regards the number and size of nodes; occasionally only one popliteal node is found. The lymphatic vessels may then be followed in the thigh, where one, several, or even a bundle of lymphatic vessels may be seen

a b c

Fig. 4. Transition of the deep lymphatic system of thigh to the pelvic system. b) Arteriography of the femoral artery. c) Lymphography both of the deep system of thigh and the medial superficial system of lower limb.

accompanying the femoral artery to the inguinal region and then running on into the pelvis (Figs 3 c, 4 a). These vessels sometimes proceed through the deep-seated inguinal nodes. Fig. 4 b demonstrates that the lymphatic vessels accompany the femoral artery. In the a. p. projection the deep vessels lie more medially in the distal parts of the thigh; the nearer to the inguinal region the more the systems are superimposed (Fig. 4 c). In the lateral projection the two systems are actually superimposed, but may, however, be distinguished, particularly in the popliteal region.

Discussion

The above method is employed in our clinic as a routine in those cases in which the lymphatic systems of the popliteal region and the thigh have to be examined, *i. e.* in cases of oedema following fracture of the

a b

Fig. 5. Lymphogram of lower limb of patient (49 years) after osteosynthesis of femur. b) Lateral. c) Thigh a.p.

1 — Posterior superficial lymphatic vessel of calf
2 — Superficial popliteal node
3 — Deep popliteal nodes
4 — Deep lymphatic vessels of thigh
5 — Transition of deep lymphatic vessel of thigh to superficial vessel below fracture
6 — Superficial inguinal node

femur or tibia, and diseases of the deep arteries and veins. If required, the method is supplemented by an injection of the lateral or medial superficial systems of the calf and thigh. Since we are chiefly concerned here with the method itself only a few examples of its application will be given.

A case of fracture of the femur treated with a Kuntscher nail is showed in Fig. 5. A practically normal transition of the superficial to the deep system was found in the popliteal region. In the region of the fracture, however, one of the deep vessels ran to the superficial part of the thigh and entered the superficial inguinal node (Fig. 5 b). On the

a b

Fig. 6. Lymphogram of patient (24 years) after supracondylar fracture of the femur. a) a.p. b) lateral.

1 — Deep lymphatic vessels of calf lying along fibular artery
2 — Deep popliteal lymphatic nodes

other hand, in a comminuted supracondylar fracture of the femur we found that the region of the heel was drained by a deep vessel which accompanied the fibular artery, thus replacing the posterior bundle of superficial vessels of the calf, which apparently did not function (Fig. 6). This view is supported by the observation that the lymphogram of the other limb showed no such changes.

The method described has proved successful in clinical practice and given valuable information of that part of the lymphatic system.

SUMMARY

A method of direct lymphography is described which enables the demonstration of the deep lymphatic system of the popliteal region and of the thigh.

ZUSAMMENFASSUNG

Eine indirekte Methode der Lymphographie wird beschrieben. Sie ermöglicht die Darstellung der tiefen Lymphbahnen der Kniekehle und des Oberschenkels.

RÉSUMÉ

Description d'une lymphographie directe, permettant de rendre visible le système lymphatique profond de la région poplitée et de la cuisse.

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SKELETAL CHANGES IN SARCOIDOSIS

by

Folke Knutsson

The histology of certain skeletal changes in sarcoidosis was described by SCHAUMANN in 1926. He demonstrated the presence of granulation tissue in bone marrow of the same type as in the glands and other organs. Granulation tissue occasionally occurred in the bone marrow without concomitant alteration in the bone structure, so that the conditions for roentgenologic changes were absent; in other cases the granulation tissue caused erosion, fragmentation, or total destruction of the bone tissue. The bone changes consisted of a general enlargement of the lacunar cavities if the process was widely distributed or in localized destruction when it was limited. In addition SCHAUMANN found that the granulation tissue sometimes continued through the Haversian canals and lead to destruction of the compact bone as well as invasion of the periosteum. He also observed healing of the granulation tissue by fibrosis.

The roentgenologic diagnosis of these skeletal changes has been described in several publications and three different types of changes have been distinguished (HOLT et coll., STEIN et coll.): (1) Single or multiple rounded destructed areas in the epiphysis surrounded by normal bone (punched-out lesions); (2) A diffuse type in which the cortex of the bone is thin and the medullary portion is widened, with a reticular pattern of the trabeculae (honeycomb or latticework configuration); (3) Mutilating type.

Submitted for publication 23 December 1958.

Skeletal changes occur in 15 to 20 % of sarcoidosis cases. The changes may occur in the bones of the hand and foot and are especially frequent in the phalanges. Extention of the process into the lacunar cavities in the larger skeletal parts as a rule causes no roentgenologically demonstrable changes (STEIN et coll.).

It is of importance to discover and study the course of the destructive processes by periodic roentgen examinations although in only a few publications has this method been reported (HOLT et coll., GOTTLIEB, COLE, FITZGERALD, MEENEN). By recording the progression or regression of the process and thereby determining its activity, insignificant variations in the bone structure may be disregarded.

No similarity between the course of the bone changes and the lung changes has been established.

a b

Fig. 1. a) Structural changes in the proximal and distal phalanges of the little finger. b) 18 months later. The changes have diminished but a small punched-out area remains in the distal phalanx.

Case report

Woman, aged 54, with lung symptoms due to extensive parenchymal changes. (The clinical diagnosis of sarcoidosis was verified by autopsy.)

Structural changes were demonstrated roentgenographically in the proximal and distal phalanges of the little finger (Fig. 1), the middle phalanx of the ring finger (Fig. 2), and the proximal phalanx of the middle finger (Fig. 3) of the right hand. The bone structure was decalcified and partially destroyed in a small localized area; only in Fig. 2 is the entire phalanx involved, marked thinning of the cortex being evident. Eighteen months later these structural changes had almost disappeared and the appearances had become practically normal. The process has not disappeared in Fig. 3 although it has undergone a definite reduction in size; a small, punched-out area remains in the distal phalanx of the little finger (cf. Fig. 1).

The case shows two types of bone changes:

1. Definite defects in the bone structure, often in the form of punched-out lesions (Fig. 1 distal phalanx); these presumably consist of fibrous tissue which has replaced the granulation tissue. This type of healing has been described by SCHAUMANN.

2. Temporary structural changes. These alterations may partially or completely disappear. Since such changes are often difficult to evaluate in one examination, because of their small size and diffuse outline, repeat examinations are necessary.

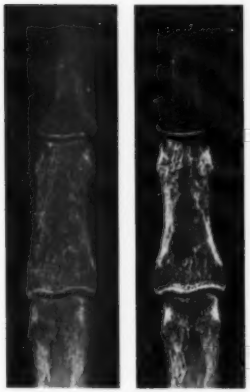

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Fig. 2. a) Structural changes in the middle phalanx of the ring finger. b) 18 months later the changes have almost disappeared.

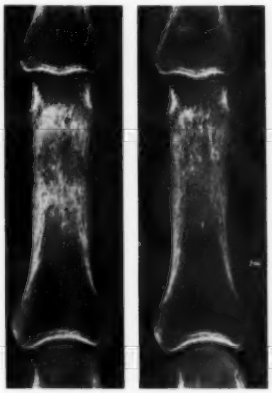

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Fig. 3. a) Structural changes in the proximal phalanx of the middle finger. b) 18 months later. The process has regressed and the appearance is almost normal.

Nearly complete healing is shown to have occurred. It is shown by Fig. 3 that a definite reduction in the lesion has taken place during an observation period of eighteen months. Had the examination of the lesions in this case been made at a later date the result might well have been negative.

It would therefore appear to be advisable to recommend repeated examinations of the bones of the hand and foot in sarcoidosis, since the structural changes may be temporary and therefore occur only during a limited period of the disease.

SUMMARY

Certain changes in the bones of the hands and feet which occur in sarcoidosis are described and discussed. An illustrative case is included. As the changes may run a temporary course, the importance of repeat examinations during the course of the disease is stressed.

ZUSAMMENFASSUNG

Gewisse Veränderungen in den Hand- und Fussknochen, die bei Sarkoidosis auftreten, werden beschrieben und diskutiert. Ein anschaulicher Fall wird inkludiert. Die Veränderungen können temporär auftreten und daher wird die Bedeutung wiederholter Untersuchungen während des Krankheitsverlaufes betont.

RÉSUMÉ

L'auteur décrit et étudie certaines modifications osseuses des mains et des pieds qui apparaissent dans la sarcoïdose. Il en rapporte un cas. Etant donné que ces modifications peuvent être temporaires, l'auteur insiste sur l'intérêt d'examens répétés pendant l'évolution de cette affection.

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PERCUTANEOUS SELECTIVE ANGIOGRAPHY OF THE INTERNAL MAMMARY ARTERY

by

Ored Arner, Paul Edholm and *Per Ödman*

The internal mammary artery has been studied angiographically in connection with thoracic aortography in patients with coarctation of the aorta. It has also been filled with contrast medium after injection into the subclavian artery. With these methods, however, the filling is poor, and at the same time adjacent arterial branches are filled. These disadvantages may be avoided if selective injection into the internal mammary artery is performed.

The technique is based on percutaneous catheterization with a radiopaque catheter, the smallest sized KIFA model with the corresponding polythene catheter being employed; this is 50 cm in length, sharply bent at the distal end (Fig. 1), the bore admitting a 1 mm thick nylon guide. With the aid of the guide, the catheter is introduced into the brachial artery by Seldinger's technique and is then manoeuvered under fluoroscopic control until the tip lies in the proximal part of the internal mammary artery. A few comments on the actual catheterizing procedure, based on practical experience, may be of interest.

It is well known that an artery, especially in fairly young women, tends to contract around the catheter (LINDBOM, and WICKBOM & BART-

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Fig. 1. Distal curve of radiopaque polythene catheter for internal mammary artery.

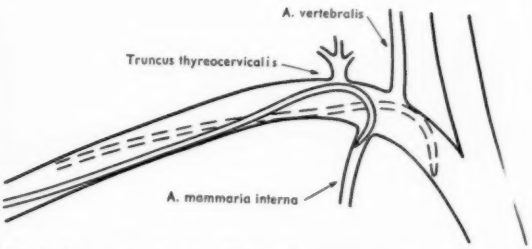

Fig. 2. Schematic drawing illustrating manoeuvring of the catheter. The catheter is first inserted into the brachial artery (interrupted lines) and thereafter withdrawn a little (full lines) so that its tip slips into the internal mammary artery.

LEY), and this makes it difficult to move the catheter up to the desired position. To avoid this, the catheter should be at once pushed far enough to ensure that its tip lies in the subclavian artery. From this point, only very small movements are required to manoeuver it into the internal mammary artery.

Owing to the sharp distal bend in the catheter, the tip during its passage upwards in the brachial and axillary artery is sometimes caught in side branches, such as the subscapular artery, the lateral thoracic artery, the thyreocervical and costocervical trunks, and the vertebral artery. Unfortunately the nylon guide is so flexible that it does not straighten out the bend in the catheter. To be quite sure that no catheterization of the side branches takes place the nylon guide may be replaced by a Seldinger guide wire (PE 160), the rigid end of which is inserted first; this wire will not pass through the small distal hole in the catheter and thus the possibility of any injury being sustained by the vessel wall is avoided.

The catheterization is carried out under fluoroscopic control with the patient supine. When the tip of the catheter is in the subclavian artery it points in a caudal direction and is superimposed over the lateral part of the vertebral bodies. If it is now drawn out cautiously so as not to alter the caudal direction of the tip it usually catches in, and even penetrates a short distance into, the internal mammary artery (Fig. 2). The tip is now directed caudally, laterally and frontally in the vessel. This situation may be clearly seen when the patient is turned so that the tip is projected over the neck of the second rib or immediately below it, 1 to 2 cm lateral to the vertebral column.

It is fairly easy to catheterize the vessel under ordinary conditions, but deformations due to pathologic changes or previous radiation therapy may cause difficulties. In such cases, some trouble may be experienced

Fig. 3. Selective angiography of the internal mammary artery, showing intercostal arteries and their branches running along the upper (→) and lower (↣) margins of the ribs. Branches run to the mediastinum and sternum (↠).

in keeping the tip of the instrument pointing in a caudal direction. In doubtful cases a test examination will often provide valuable information on the local topography of the vessels. For this, 5 to 7 ml of contrast medium (Urografin 30 %) are injected manually with the catheter tip in the subclavian artery, *i. e.* at a point situated definitely proximal to the origin of the internal mammary artery. In view of the proximity of the vertebral artery, it is advisable to be cautious as regards the amount of contrast medium.

If by the fluoroscopic appearances the catheter tip seems to be in the internal mammary artery a similar test examination should be carried

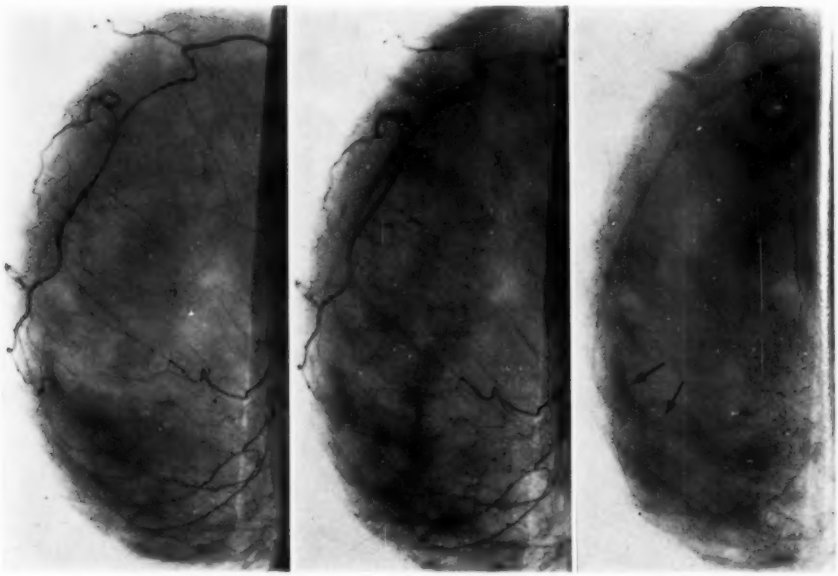

Fig. 4. Cancer of the breast. Mammary angiography. Breast compressed between plastic discs and depicted with the rays tangential to the thoracic wall. a) Arterial phase. b) Arteries and veins filled at the same time, suggesting that shunting of the contrast medium has taken place. Displacement (→). c) Parenchyma- and vein phase. Slight filling defects in the mammary tissue, particularly at the site of the tumour (→).

out before the angiographic procedure. The tip may, in fact, be lying against the wall of the subclavian artery or, if a vascular anomaly is present it may be located in a branch of the internal mammary artery. If the examination is correct in all aspects, the patient will have a sensation of warmth in the entire breast and the adjacent part of the thoracic wall; if not, the proper sensation is not experienced.

The filling proper is achieved by 15 ml Urografin 45 % injected manually. With this technique the arterial phase will include the internal mammary artery and its branches, as well as some anastomoses to this vessel (Fig. 3). In the breast, not only the arteries but the veins also will appear.

The main object of this investigation, which included only 6 cases, was to seek reliable angiographic differences between cancer and fibroadenomatosis. Four of the cases had a distinctly palpable tumour, the microscopic diagnoses after operation being: carcinoma of low differentiation (Fig. 4), carcinoma with peau d'orange and infiltration in the skin (Fig. 5), fibroadenomatosis, and fibroadenomatosis with fibroadenoma.

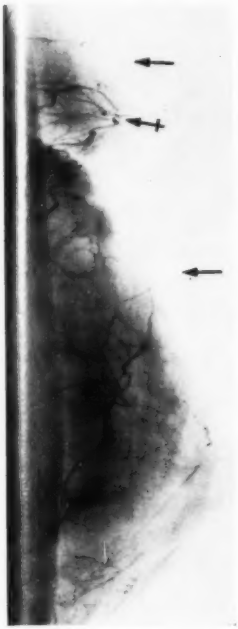

Fig. 5. Cancer of the breast. Same technique used as for fig. 4. Growth at (→), where the arteries are stretched and irregular. Dilated arteries suggesting inflammatory changes (↔) visible at the borders of the tumour.

The fifth case had undergone an ablatio mammae for breast cancer three years earlier. She now had an obvious, palpable metastasis in the axilla.

The results from these cases were indefinite. It was possible, it is true, to establish a deformation of the vascular pattern appearing as displacements or defects in the vessels, and a suggestion of peripheral hypervascularization in the area of the tumour. But nothing typical of the one or the other type of process was obtained, despite the fact that the tumours in question were far advanced. The method thus cannot have any definite differential diagnostic significance.

The sixth case had a rib fracture and was examined by arteriography of the internal mammary artery for the purpose of studying the rib arteries. The latter were found to be intact.

A positive result of the investigation is that the method makes it possible to study areas communicating with the internal mammary artery, as may be seen from Fig. 3.

SUMMARY

A technique for percutaneous selective angiography of the internal mammary artery is described. The method has been used in the examination of tumours of the breast. When a tumour is present, changes in the vascular pattern may be demonstrated but no definite conclusions regarding the nature of the process can be drawn.

ZUSAMMENFASSUNG

Eine Technik für die perkutane selektive Angiographie der Arteria mammaria interna wird beschrieben. Die Methode ist bei der Untersuchung von Brusttumoren benutzt worden. Liegt ein Tumor vor, können Veränderungen des Gefässmusters nachgewiesen werden. Definitive Schlussfolgerungen bezüglich der Natur des Prozesses können jedoch nicht gezogen werden.

RÉSUMÉ

Les auteurs décrivent une technique d'angiographie percutanée sélective de l'artère mammaire interne. Cette méthode a été utilisée pour l'examen de tumeurs du sein. Quand il y a une tumeur, on peut mettre en évidence des modifications de la vascularisation, mais on ne peut en tirer de conclusion nette concernant la nature de la tumeur.

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR: ERIC SELANDER), LÄNSLASARETTET, MÖLNDAL, SWEDEN

CONTROLLED PARAVERTEBRAL INJECTION OF HYDROCORTISONE IN CERVICAL RHIZOPATHY

by

Stig Olsson

The cervical nerve root syndrome is a well-known clinical entity in everyday practice. The treatment of this often severe and painful condition has so far been mainly physical (massage, short wave diathermy, traction, etc) or roentgen treatment. A fair number of patients, however, prove to be resistant to such treatment and other methods have therefore been tried including the anti-inflammatory action of hydrocortisone, injected locally.

COHEN et coll. (1955) have described a method of injecting hydrocortisone paravertebrally in the cervical region. The technique was described as simple; after the pain had been localized (at the back of the head or radiating towards a shoulder or arm), hydrocortisone was injected at the appropriate level in the neck. The dose was 25 mg and the number of injections varied from 2 to 21 at intervals of 1 to 2 weeks. The case material included 26 patients with a history of pain of from two weeks up to five years. No information was given as to whether any other treatment such as physiotherapy or roentgen irradiation had been tried previously. The injections are reported to have relieved the pain considerably in 8 patients, moderately in 7, slightly in another 7, while no effect was noted in 4 cases. Apart from the initial pain and irritation

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Illustration of the injection procedure. Patient seated as for a routine oblique view of the cervical spine. Film for controlling the position of the needle is obtained by placing the cassette in front of the image intensifier. The position is corrected by further fluoroscopy before the injection.

in connection with the actual injection in individual subjects, no side-effects or complications are mentioned.

Cervical spondylosis and the associated symptoms of nerve root compression are both of diagnostic and therapeutic interest to the radiologist. So far, roentgen irradiation has played a considerable part in the treatment but its effect has in many cases been uncertain.

We have selected a number of cases for paravertebral injection of hydrocortisone controlled by means of a Philip's image intensifier Müller BV 20. By using this method it is possible to introduce the hydrocortisone where desired and avoid injection into the intervertebral foramina. The point of the needle is directed against the postero-lateral region of the intervertebral disc in question at the site of the so-called unco-vertebral joint. (See figure.) The patient is seated in the same position as for an ordinary oblique roentgenogram of the cervical spine. A suitable level for inserting the injection needle is determined by fluoroscopy. Any unpleasant sensation is reduced by a local anaesthesia of 1 % Xylocaine. The needle is directed medially and posteriorly, usually posteriorly to the common carotid artery, anteriorly to the vertebral artery, and medially to the brachial plexus; it is then advanced towards the disc in question until bone resistance is felt. After the position of the point of the needle has been checked by fluoroscopy and the plunger of the syringe slightly withdrawn as usual, 1 ml (25 mg) of the hydrocortisone suspension is infiltrated into the region.

So far, only 12 patients have been treated, all of these as out-patients. Several of the patients had previously received roentgen and other treatment but with no or only slight effect. All had suffered from considerable

Table

Survey of treatment with controlled paravertebral injection of hydrocortisone in 12 patients with cervical rhizopathy

Sex and age	Duration of disease	Previous treatment	Level of injection	Number of injections	Effect*	Time of observation
F 46	> 2 yrs	Roentgen	C_5—C_6	1	+++	3 months
F 37	5 yrs	—	C_5—C_6 C_7—Th_1	1 2	+++	1 month
M 53	> 3 months	—	C_6—C_7	3	++	1 month
F 57	1 month	—	C_6—C_7	2	+++	1 month
M 50	6 months	Roentgen	C_5—C_6	1	0	3 weeks
M 51	> 1 month	»	C_6—C_7	1	+++	1 year
M 44	> 3 months	—	C_5—C_6	2	+++	1 month
F 77	1 month	—	C_5—C_6	2	+	1 month
M 61	> 2 yrs	Roentgen	C_6—C_7	1	0	2 weeks
F 52	> 1 year	»	C_6—C_7	1	++	1 week
F 49	1 month	»	C_5—C_6	1	++	1 week
F 58	> 1 year	»	C_6—C_7	1	++	1 week

* +++ complete freedom from pain, ++ marked relief, + slight relief, 0 no effect.

pain in one or both shoulder regions often radiating onto the arm or arms; in some cases numbness had been experienced as well. The duration of the condition had varied from about one month up to five years.

Conventional roentgenograms of the cervical spine were first obtained. These showed changes localized around one or at the most two discs, usually between C5 and C6 or C6 and C7 with constriction of the corresponding intervertebral foramen (partly from the unco-vertebral joint and partly from the 'true' joint). All the patients treated had free mobility of the shoulder joints. On the whole the correlation between the clinical picture and the roentgen findings was good. The number of injections varied from one to three. Whether relief of pain was attained or not, it has not been considered advisable to give more than three injections. The intervals between the injections in the present cases were from 1 to 2 weeks. Apart from temporary local pain in one case and the occurrence of Horner's syndrome of short duration in another, no side-effects or complications were observed. The results of the injections have been encouraging (see Table). Most of the patients have experienced marked relief; in two cases an almost dramatic effect was obtained with freedom from pain after years of suffering.

The irradiation dosage received by the patients and personnel ma be minimized with the usual protection in a room with subdued ligh (DIETHELM et coll. 1956, KOCKUM et coll. 1958). The exposure time ma easily be checked by a panel-mounted chronometer and, after a certai amount of practice, need not exceed one or two minutes at a low kil voltage and milliamperage.

Finally it may be mentioned that experiments with the controlle paravertebral injection of hydrocortisone into the lumbar region hav been made in a few cases. The case material is at present too small fo definite conclusions to be drawn but the results so far have suggeste that the method may also be of considerable value in this part of the spin.

SUMMARY

Controlled paravertebral injections of hydrocortisone in conjunction with a Müll BV-20 image intensifier have been tried in a series of 12 cases of localized cervica spondylosis with severe symptoms. The results indicate that the method compare favourably with roentgen treatment.

ZUSAMMENFASSUNG

Kontrollierte paravertebrale Hydrocortisoninjektionen unter Benutzung eine Müller BV20-Bildverstärkers sind in einer Serie von 12 Fällen mit lokalisierte Halsspondylosis und schweren Symptomen versucht worden. Die Resultate zeigen, dass die Methode vorteilhaft mit der Röntgenbehandlung verglichen werden kann.

RÉSUMÉ

Sur une série de 12 cas de spondylose cervicale localisée avec symptômes graves, on a essayé de faire des injections paravertébrales d'hydrocortisone contrôlées au moyen d'un intensificateur d'image Müller BV-20. Les résultats montrent que cette méthode supporte avantageusement la comparaison avec la roentgenthérapie.

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR: H. ÖDEGAARD), SENTRALSYKEHUSET, FREDRIKSTAD, NORWAY

INVAGINATION OF THE ESOPHAGUS IN HIATUS HERNIA

A report of 8 cases

by

Haakon Ödegaard

During the last decade it has been shown that the mucosa of the esophagogastric junction under physiologic conditions is capable of considerable automatic migration, presumably through contraction of the muscularis mucosa (3), (5). In the presence of relaxation of the esophagogastric opening a retrograde prolapse of the redundant gastric mucosa into the lower part of the esophagus may occur (1), and this may cause dysphagia, regurgitation, vomiting, and epigastric distress (9).

The other type of invagination at the esophagogastric junction — that of the esophagus into the stomach — is very seldom mentioned in the literature. This is nearly always seen in connection with a sliding hiatus hernia (4, 7, 8). A rare form of invagination of an elongated and dilated esophagus with a contracted cardiac orifice into the stomach below the diaphragm has been described (2).

KLINEFELTER in 1956 was able to collect 11 cases of esophagogastric invagination from the literature and add a report of 3 of his own cases. He claims that this condition is not uncommon but does not indicate its frequency. He draws attention to the fact that on roentgen examination the appearance of the invaginated esophagus into the hiatus hernia often resembles a 'Jack-in-the-pulpit'.

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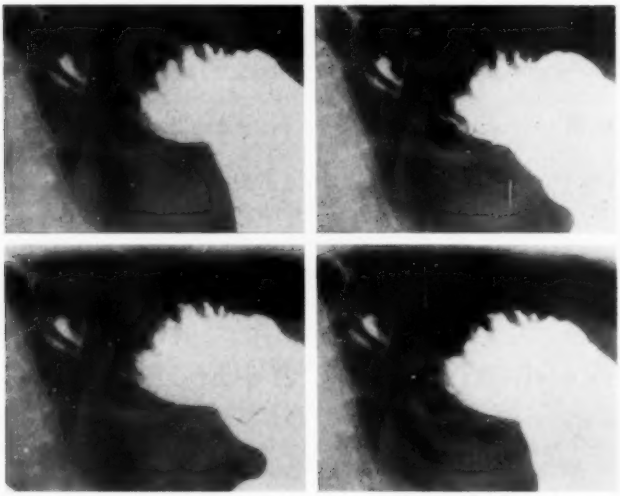

Fig. 1. Case 1. Small sliding hernia with esophagogastric invagination.

The incidence of hiatus hernia in patients referred to us for barium meal examination is between 2 and 3 per cent. From January 1957 till March 1958 35 cases were encountered of whom 4, 1 male and 3 females, had paraesophageal, and 31, 7 males and 24 females, had a sliding hernia. In the 31 cases of the latter, roentgenologic signs of esophagogastric invagination were found in 8, 7 of whom were females.

Case reports

Case 1. Woman, aged 54, was admitted with hematemesis and melena. During the previous 10 years she had suffered from intermittent dyspepsia, but had no dysphagia or regurgitation. On roentgen examination, in addition to a duodenal ulcer, a small sliding hernia with esophagogastric invagination was demonstrated in the prone position (Fig. 1).

Case 2. Woman, aged 54, with renal carcinoma was referred for barium meal examination because of moderate peptic symptoms during the previous 18 months. No nausea, vomiting, or regurgitation. A small sliding hiatus hernia with intermittent invagination of the esophagus was disclosed with the patient prone (Fig. 2); the hernia was reducible in the erect position.

Case 3. Woman, aged 68, was referred for barium meal examination because of intermittent eructation and heartburn over a period of several years, especially when lying down. A sliding hiatus hernia, the size of a tangerine, with intermittent invagination of

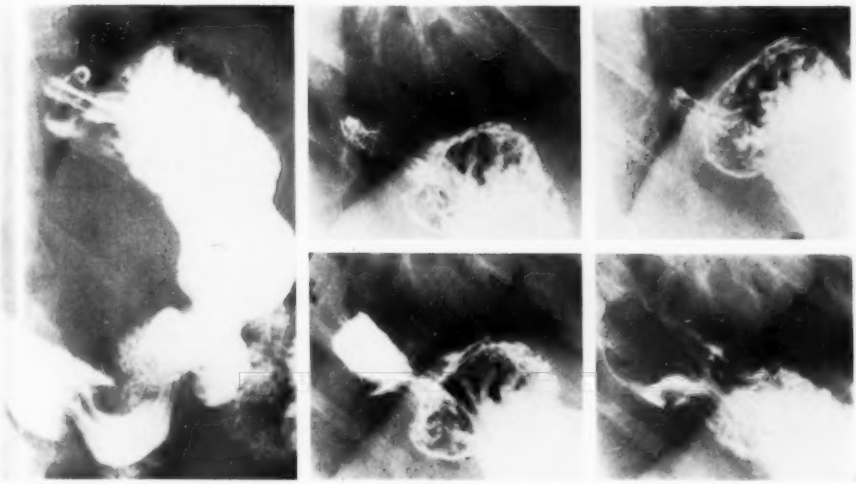

Fig. 2. Case 2. Intermittent esophagogastric invagination in the prone position. Piston effect of the contrast medium.

the esophagus into the herniated part of the stomach was revealed (Fig. 3). The hernia was not reducible with the subject erect, but the invagination was seen only in the prone position. Esophagoscopy showed coarse mucosal folds in the distal part of the esophagus. In this case Allison's operation was performed, during which no signs of invagination was evident.

Case 4. Man, aged 71, was referred for barium meal examination because two small polyps had been removed from the distal part of the stomach 2 years previously. He had no dyspepsia or dysphagia, or recurrence of the polyps. In the prone position a small sliding hernia with invagination of the esophagus was found, but in the erect posture the hernia was reducible and reduction of the invagination occurred (Fig. 4).

The four remaining cases were all of women of from 68 to 81 years of age with similar appearances of esophageal invagination into small hiatus hernias, evident in the prone position. Two of the patients had symptoms of regurgitation which could be demonstrated during fluoroscopy. Two of the hernias were reducible in the vertical position.

Discussion

These 8 cases of esophagogastric invagination in 31 consecutive cases of sliding hiatus hernia indicate that this condition is probably more

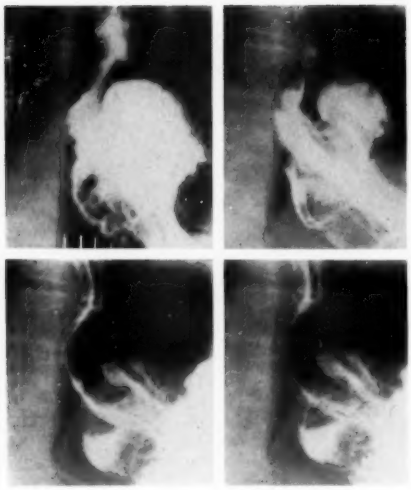

Fig. 3. Case 3. Sliding hernia with regurgitation and esophagitis. The esophagogastric invagination does not occur during regurgitation (upper left view).

common than previously assumed. Four of the patients had symptoms which could be related to a sliding hernia, and in 2 of these regurgitation of the gastric contents into the esophagus was demonstrated by fluoroscopy. In the remaining 4 cases the demonstration of a hiatus hernia was more or less coincidental.

Four of the hernias were reducible in the upright position, while 3 were not, and in 1 there was some doubt.

The esophagogastric invagination was in all cases intermittent, could be best demonstrated in the prone position, and was never seen with the patient erect. Any definite signs distinguishing a hiatus hernia with invagination of the esophagus from an ordinary sliding hernia could not be demonstrated.

The question of why and how esophagogastric invagination occurs has not been solved. In one of the 2 cases from the literature subjected to operation (8) an 'S'-like fixation of the distal part of the esophagus was found. In one of our cases operated upon (3) nothing but an ordinary sliding hernia was seen. In 2 of our cases in which esophagoscopy was performed, inflammatory changes were evident in the distal part of the esophagus. In one of these cases the mucosa of the distal part of the esophagus could be seen moving upwards — during the relaxation of the hiatus — producing the appearance of a moving cervix. In this case the hiatus hernia and the invagination were demonstrated in the prone position only, while the esophagoscopy was performed with the patient supine. It may therefore be assumed that the same mucosa which was seen moving upwards during the esophagoscopy would be intermittently invaginated into the herniated part of the stomach in the prone position.

How much of the esophageal wall takes part in the invagination can hardly be estimated from the roentgen appearances although most of our series are compatible with an invagination of the mucosa only. The roentgen appearances in esophagogastric invagination resemble those seen in transpyloric prolapse of the gastric mucosa, which in many instances does not cause any specific symptoms either (6). In Case 2 (Fig. 2) it is

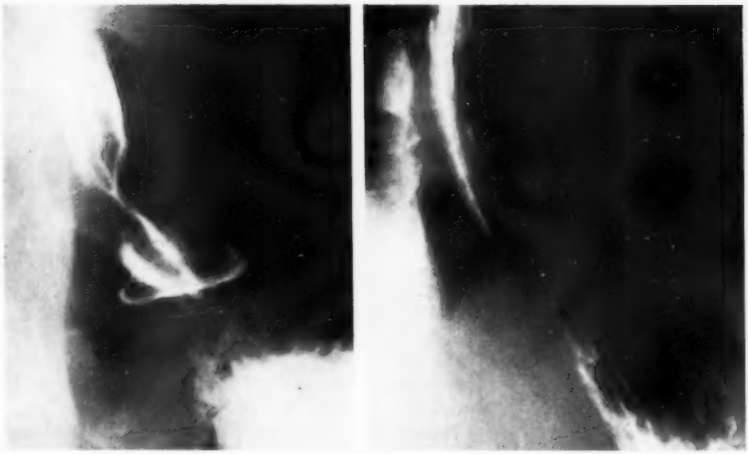

Fig. 4. Case 4. Typical 'Jack-in-the-pulpit' appearance of the invaginated esophagus into a small sliding hernia in the prone position (left). Normal appearances with subject erect (right).

possible that the intermittent invagination may be explained by a sort of piston effect from the bolus of the barium contrast medium while passing through the cardiac orifice.

SUMMARY

Among 31 consecutive cases of sliding hiatus hernia in which barium meal examination was performed, eight cases of intermittent esophagogastric invagination were found. Any specific symptoms related to the invagination could not be found. The esophagogastric invagination may probably be explained by a prolapse of the esophageal mucosa through the cardiac orifice.

ZUSAMMENFASSUNG

Unter 31 konsekutiven Fällen mit einem Zwerchfellgleitbruch bei denen man Untersuchungen mit einer Kontrastmahlzeit durchführte wurden 8 Fälle mit intermittenter ösophago-gastrischer Invagination gefunden. Keine spezifischen Symptome, die auf die Invagination zurückzuführen wären, wurden beobachtet. Die ösophago-gastriche Invagination kann wahrscheinlich durch einen Prolaps der Ösophagusschleimhaut durch das Orficium cardiae erklärt werden.

RÉSUMÉ

L'auteur a trouvé sur 31 examens par repas baryté de hernie hiatale par glissemen huit cas d'invagination oesophago-gastrique intermittente. Il n'a trouvé aucun symptôm caractéristique en relation avec l'invagination. L'invagination oesophago-gastrique peu probablement être expliquée par un prolapsus de la muqueuse oesophagienne à traver l'orifice du cardia.

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR: YRJÖ V. PAATERO), INSTITUTE OF DENTISTRY, UNIVERSITY OF HELSINKI, FINLAND

STEREOSCOPY IN ORTHORADIAL PANTOMOGRAPHY OF THE JAWS

by

Yrjö V. Paatero

Since stereoscopy has been successfully adapted to ordinary pantomography (PAATERO 1954) theoretical and experimental investigations into the possibility of obtaining equally good stereoscopic effects with the new pantomographic method 'orthoradial pantomography' (or 'orthopantomography' for short), were considered to be justified.

In spite of the fact that both methods are based upon similar fundamental principles, there are, however, certain differences in their application. For instance, while the object rotates about a single rotation axis in the 'old' method, three rotation axes are used in orthoradial pantomography (PAATERO 1958). The lateral parts of the maxilla and mandible are exposed when the object is in an eccentric position, and rotating about the main rotation axis O (O_1) (Fig. 1); the anterior parts are exposed when the patient's head is in a concentric position and rotation occurs about axis T. The turning from the first eccentric position to the second takes place about axis A. The arrows indicate the direction of the roentgen beam at different points of the mandible. Circle d corresponds to the curvature of the anterior region PP_1 of the dental arch and circles D and D_1 to the lateral regions.

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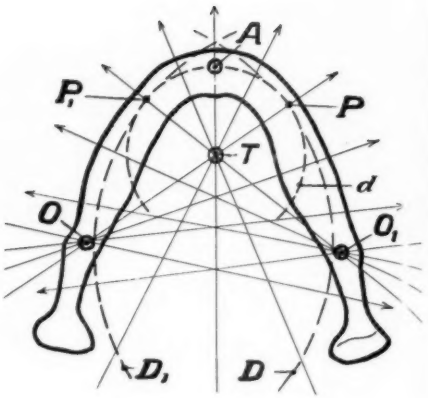
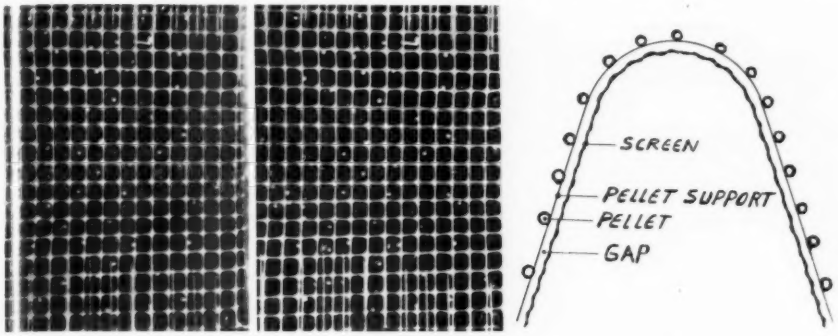


Fig. 1. Theory of orthoradial pantomography. Arrows indicate direction of roentgen beam at different points of the mandible. $O(O_1)$ — main rotation axis; A and T — accessory axes.) The object turns about axis A from the first eccentric position to the second. When the lateral parts of the jaw pass the roentgen beam, the patient's head rotates about axis O (O_1); the object rotates about axis T when the anterior parts P_1AP, are in alignment.

Radius TP should be about 3 cm, while radius OP (O_1P_1) may vary within limits of from 6 to 10 cm or in practice perhaps even more. As can be seen, the projection is orthoradial (perpendicular) for nearly the whole extent of the mandible; only the most posterior points, such as those in the regions of the condyles, will be projected somewhat obliquely.

Since radius OD (O_1D_1) is at least twice as great as radius Td, the image layer of the lateral parts will be considerably thicker than the image layer of the anterior parts and the stereoscopic effect may therefore also be expected to differ at correspondingly different areas of the jaws, as shown in previous publications (PAATERO 1954).

Experiments with metal phantoms showed, however, that the stereo-effect is, in practice, equal in the anterior and the lateral parts of the jaws. Fig. 2 a shows the result of an experiment made with the phantom depicted schematically in Fig. 2 b. A metal gauze screen was placed in front of a film, lead pellets attached to a sheet of celluloid being positioned about 6 mm further away. The screen and the film passed the roentgen beam with equal linear velocity. Hence, the pellets move a little faster than the screen and the film, when passing the beam, and appear somewhat blurred in the orthoradial pantomogram. If we examine the stereo-components stereoscopically we see that the gap between the screen and the pellets is equal throughout the tri-dimensional view. In addition, the screen and the pellet surface appear flat in spite of being bent to correspond to the shape of the mandible. It was indeed to be expected that the phantom would appear flat in the stereoscopic view because the distances from the focus to the image layer and to the film remain constant throughout the exposure. In the 'old' pantomographic method these distances vary and hence the upper and lower jaw in stereo-pantomograms appear as more or less curved (PAATERO 1954).



a b

Fig. 2. a) Stereoscopic orthoradial pantomogram of a metal phantom with vertical tube shift. The phantom consists mainly of a screen and lead pellets positioned to correspond to the shape of the mandible. b) Diagram of the phantom represented in (a).

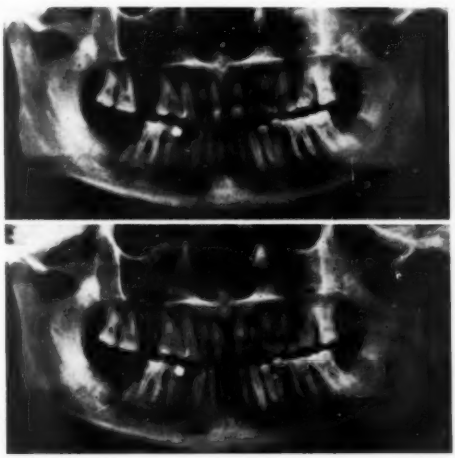


Fig. 3. Stereoscopic orthoradial pantomogram of the jaws of a dry skull with vertical tube shift. If the eyes are crossed the jaws are seen from the outside, if looked at with the eyes parallel, from the inside.

As in ordinary stereo-pantomography the roentgen tube may be shifted horizontally or vertically between the exposures with good results. The general laws of stereoscopy should naturally be kept in mind (Hasselwander 1954, Mannila 1956 and Paatero 1954).

A stereoscopic ortho-pantomogram of the jaws obtained by a horizontal tube shift technique is being published elsewhere (Paatero 1958),

and only one stereoscopic view obtained with the vertical technique is now included (Fig. 3). When the stereo-components are looked at with the eyes crossed, the jaws are seen from the outside, but if examined with the eyes parallel, from the inside. The films are of a dry skull taken with a small experimental hand-operated apparatus, a photograph of which has previously been published; a prototype for clinical use is under construction. It should be pointed out that the rotation of the chair is replaced by a rotation of the roentgen tube and cassette around the patient by means of a suitable mechanism. The essential requirements are that the mutual movement of the three principal factors are correct and that the apparatus functions smoothly.

SUMMARY

Theoretical and experimental investigations have shown that good stereoscopic films may be obtained in combination with the 'orthoradial pantomographic method' with either an horizontal or vertical tube shift. The jaws appear flat in ortho-pantomograms and not curved as in ordinary pantomograms.

ZUSAMMENFASSUNG

Theoretische und experimentelle Untersuchungen haben gezeigt, dass man gute stereoskopische Bilder durch Kombination der 'orthoradialen pantomographischen Methode' mit entweder horizontalen oder vertikalen Röhrenverlauf erhalten kann. Die Kiefer sehen in den Orthopantomogrammen flach aus, nicht gebogen, wie in gewöhnlichen Pantomogrammen.

RÉSUMÉ

Des recherches théoriques et expérimentales ont montré qu'on peut obtenir de bons films stéréoscopiques par la méthode 'pantomographique orthoradiale', avec un déplacement du tube horizontal ou vertical. Sur les ortho-pantomographies, les maxillaires paraissent plans et non courbés comme sur les pantomographies ordinaires.

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PRIMARY AND SECONDARY STANDARDS OF ROENTGEN RADIATION

in the HVL range 1.6 mm Al—15 mm Cu

by

Boyce Worthley and *John Tooze*

For roentgen rays generated by potentials in the range 10 to 250 kV the roentgen is realised by means of free air chambers. As it is not easy to build free air chambers for roentgen rays generated by potentials in excess of 500 kV, it is customary to use cavity ionization chambers for dosage measurement in the supervoltage regions. When calibrating sub-standard thimble chambers for response to roentgen rays in the range 1 mm Al to 15 mm Cu, it is necessary to use two primary standard ionization chambers of completely different design. Large jumps have been reported (8) in the values of quality correction factors when proceeding from 1 mm Cu HVL to 10—15 mm Cu, and it is not altogether clear whether such large changes are caused by the nature of the sub-standard thimble chamber or by the discontinuity in standardization procedure. To investigate this point, twelve thimble chambers were examined in the quality range 1.63 mm Al to 2.06 mm Cu HVL using a free air chamber, and at 15 mm Cu HVL using a cavity chamber. Five of these thimble chambers were the property of the University of Adelaide and the remaining seven were supplied by the other major radiotherapy centres of Australia. Seven dosemeters were examined, including five Model 70 Victoreens, one Victrometer, and one Mark 2 Baldwin Farmer, and most

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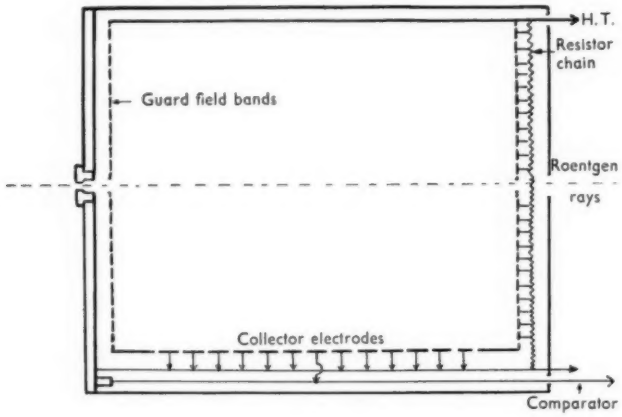

Fig. 1.

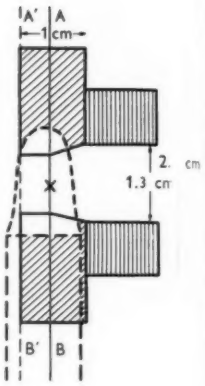

Fig. 2.

Fig. 1. Free air chamber. Holes in the Perspex box provide free passage for roentgen rays.

Fig. 2. Free air chamber diaphragm, indicating position of replacement for thimble chambers.

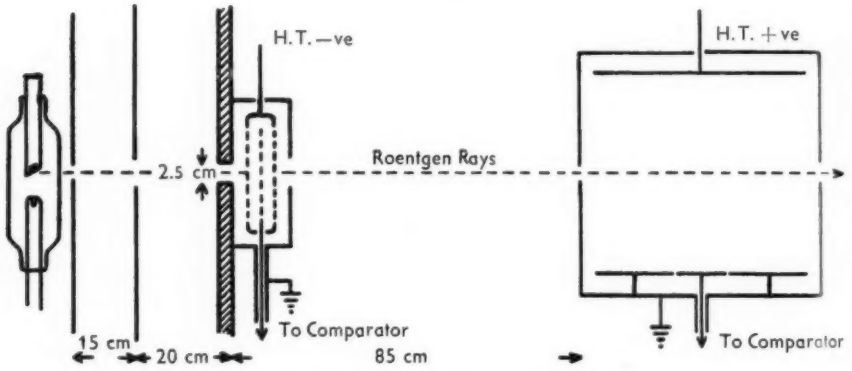

Fig. 3. Arrangement of chambers and diaphragms.

of the work was done over the period of a month or two. Sufficient detail of the method and correction factors used in this work will be given so that the results may be compared with those obtained elsewhere.

Primary standardization method HVL range 1.63 mm Al to 2.06 mm Cu

The free air chamber. Over the last 6 years several free air chambers have been built. These include a small chamber of plate separation 3.25 cm, a copy of the N.B.S. old model of plate separation 12 cm, and an experimental chamber of plate separation 25 cm. The large experimental chamber has been greatly modified during the course of a lengthy study of the design of free air chambers.

In its present (and by no means final) form, the chamber used for the reported work was of parallel plate type with plate separation 25 cm, collector width 2 cm, collector length 33 cm, and depth of chamber in the direction of the roentgen beam 35 cm. The collector electrode system is enclosed in a guard field box of graphited Perspex sheet. The inner surface of the box is divided into conducting bands (each 1 cm wide) by scribing shallow cuts through the conducting surface into the Perspex. Using a resistor chain the high tension graded down four walls of the box from 4000 volt positive to earth potential. This system replaces the more usual guard wire field corrector and was selected after study of various systems using an analogue computer (4).

Fig. 1 illustrates the principal features of the free air chamber. The essential elements of the three diaphragms for the free air chamber are shown in Fig. 2. The defining aperture which is cylindrical for 4 mm and then tapers gently for 6 mm, is set in lead of thickness 1 cm, diameter 4 cm. The lead is mounted on a steel cylinder of I.D. 1.3 cm and O.D. 2.5 cm situated in the front of the free air chamber. The diameter of the base of each aperture was measured using a reading microscope, the value taken being the mean of the measurement of eight diameters.

The effective width of the aluminium collector plate was measured using the reading microscope and includes half of the space on each side adjacent to the guard plates. The value accepted was the mean of 11 values taken at intervals down the length of the collector.

Table 1

Aperture	Mean diameter in mm	Area in cm²	Mean collector width in mm
1	5.0019 ± 16	0.1965	20.279
2	8.498 ± 2	0.5672	
3	11.170 ± 3	0.9799	

The distance of the middle of the collector volume from the back of the cylindrical hole in the diaphragm was 20 cm and the following absorption factors (3) were taken.

Table 2

kV constant potential	HVL in mm	k
60	1.6 Al	1.0112
120	3.0 Al	1.0089
190	0.26 — 2.06 Cu	1.0056

The focus chamber distance was approximately 120 cm and the preliminary aperture, a few centimetres in front of the focus 1 cm in diameter. The arrangement of the apparatus was as illustrated in Fig. 3.

The thimble chambers were placed as shown in Fig. 2, calculation indicating the plane AB to be the most suitable position for the centre of the substituted thimble. Chambers are replaceable to this point certainly to within $\pm$ 0.5 mm. If the thimble is centred at the front of the aperture A^1B^1, an error of the order of 0.5 % will be incurred on the basis of the inverse square law.

A collection potential of 4 000 volt positive (160 volt/cm) was found to be adequate with aperture sizes and dose rates used to achieve within 0.1 % of saturation. Investigation of near saturation phenomena indicated that the saturation deficiency was inversely proportional to the square of the collection voltage so that the true saturation current could be calculated for a given quality of beam, dose rate and aperture. Examination of the saturation behaviour of thimble chambers indicated that saturation deficiency was dependent on $1/V^2$ over part of the collection voltage range. However, in the region of 400 volt collision ionization effects became apparent. The collection potential for the standardization of thimbles was arbitrarily set at 340 volt which was the mean potential for a chamber discharging to 50 r on the 100 r scale.

The most difficult condition to ensure is that the chambers are irradiated uniformly. The method used here for checking was that of comparison of ionization produced when using the 5, 8.5 and 11.2 mm diameter apertures. If the ionization was proportional to the area of the diaphragm within 0.1 %, then the field was regarded as sufficiently uniform to standardize Victoreen 100 r and 250 r chambers, the dimensions of a 100 r chamber being approximately 14 $\times$ 10 mm.

The lead thickness for the front of the free air chamber was 1 cm and its sufficiency was readily demonstrated by the use of a diaphragm of zero opening irradiated with a beam of HVL 2 mm Cu for the usual time of charge collection. No registration was observed.

Comparison of the experimental chamber with a copy of the N.B.S. old free air standard of plate separation 12 cm indicated deficiencies of the old chamber similar to those described elsewhere (3 and 8), and a comparison of the Adelaide 12 cm chamber with the Australian primary standard of similar design in Melbourne via a Victoreen calibration

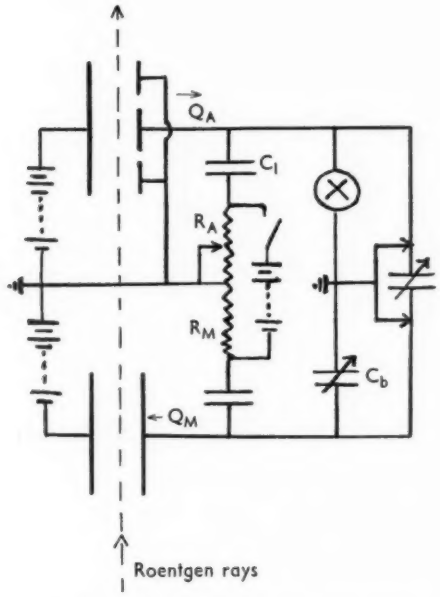

Fig. 4. Induction calibrated charge comparator.

showed that these two chambers gave identical quality correction factors within $\pm$ 1 %.

The roentgen beams were derived from a Siemens constant potential equipment, the kilovoltages and HVL of beams used were as shown in Table 3.

Table 3

kV	60	120	190	190	190	190
Added filter	Nil	Nil	Nil	0.5 Cu	1.0 Cu	Thoraeus (1 mm Al 0.25 mm Cu and 0.4 mm Sn)
HVL in mm	1.63 Al	3.0 Al	0.26 Cu	1.0 Cu	1.4 Cu	2.1 Cu

The half value layers were measured using a monitor, free air chamber and charge comparator with the HVL filters situated halfway between the monitor and free air chamber.

Charge measuring equipment. The chamber is linked with an induction calibrated charge comparator (7) illustrated in Fig. 4. The ratio of charges generated by the passage of roentgen rays through a nylon mesh monitor and the free air chamber is derived by means of a resistance box, the

ratio Q_a/Q_m being proportional to the resistance R_a. The free air chamber is then replaced by a thimble chamber and the ratio of thimble to monitor charges Q_v/Q_m is again derived by the value of the resistance R_v and

$$Q_a/Q_v = R_a/R_v$$

The constantan wire resistance box has been calibrated to an accuracy of 0.01 %.

Dosemeter standardization method. The charge comparator readings were converted to correction factors M by a procedure described in detail elsewhere (6) using the formula

$$M = \frac{Q_a}{Q_v} \cdot \frac{k\ 3.24\ F(n)\ C}{v \quad 1\,000}$$

In this expression $v = A \cdot L$ (A is area of diaphragm, L is effective width of collector electrode), $F(n) = (V(o) - (V(n))/n$, where $V(n)$ is the potential corresponding to scale reading n of the Victoreen electrometer, and C is the capacitance between the inner electrode and casing when a condenser chamber is sited in the socket of a Victoreen electrometer. Both $F(n)$ and C can be measured with an accuracy of $\pm$ 0.1 %.

$Q_v/n = F(n)\ C$ may be measured directly by the following procedure: charge the Victoreen in the usual way to give zero roentgen reading, detach the condenser chamber and bleed charge via a 5×10^{12} ohm resistor into a Townsend charge measuring system. When sufficient charge has been removed, replace the condenser chamber in the electrometer socket and read scale registration n.

$Q_v = C^1 V_n^1$ where C^1 is the capacitance, and V_n^1 is the compensating potential of the Townsend system. This system is particularly useful when the Victoreen has been adjusted so that $F(n)$ is constant within a fraction of a percent.

Primary standard chamber: HVL 15 mm Cu

The essential elements in the construction of the cavity chamber used as primary standard are illustrated in Fig. 5. The material used was 3/16″ (ca 4.8 mm) Perspex sheet chosen for ease of machining and its approximation to air equivalence for supervoltage roentgen rays. Conducting surfaces were obtained using a spray of aqua dag. The upper window, facing the source of roentgen rays, was made of two discs of Perspex of diameter 10 cm. The first of 3/16″ Perspex

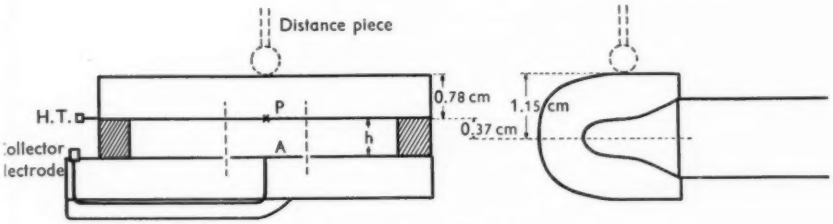

Fig. 5. Standard cavity chamber.

was graphited on the under surface to act as the high tension electrode, and the second machined to such a thickness that the two discs had an arbitrary thickness of 0.915 gram/cm² ($\varrho = 1.18$ g/cm³). Two spacer rings were made of Perspex each of O.D. 10 cm and I.D. 9 cm, one of thickness approximately 3/16″ and the other approximately 1/16″ (about 1.5 mm). The collector electrode system was made of 3/16″ Perspex sheet, surface graphited for conducting and an island of 2 cm diameter (made of scribing a circular cut in the surface of the Perspex) surrounded by a conducting surface at earth potential. The collector electrode was linked with the cable terminal by means of thin pencil lead joined by packed graphite. In use, the chamber was illuminated by a 10 × 10 field of roentgen rays so that only Perspex and graphite was irradiated. Several collector island diameters were measured using a reading microscope and the mean diameter taken. This diameter was the mean of the diameter of the island, and the diameter of the island plus insulating ring surrounding it.

The thickness of the spacer rings was also measured at several points with a micrometer and the air volume derived.

As an independent method of deriving the air volume, the capacitance C_1 between the collector plate and the H.T. plate was measured.

$$C_1 = A/4\,\pi\,h_1 \quad \text{and} \quad v'_1 = A^2/4\,\pi\,C_1 = \pi\,D^4/64C_1$$

Thus v'_1 is an estimate of the volume subject to four times the error inherent in the measurement of collector diameter (the error in C_1 is relatively small).

As $v'_1 = \pi\,D^2h_1/4$ is subject to only twice the error in the diameter, plus the error in the knowledge of h_1, the advantage in the capacitance derived volume is appreciated when it is realised that the thickness of the spacer ring is not necessarily the separation of the collector and H.T. plates due to imperfections in the Perspex sheets. The air volumes derived from the two methods of measurement agreed within 1 %, but for the reason given above, the capacitance derived value was accepted. The ionization response also was closely proportional to these values.

The correction factor for the near air equivalence of Perspex was that of WHYTE (5), the value $B = 0.979$ being accepted.

The charge measurement system was the Townsend method described by FRY (2). The capacitor was of value 1 026 pF calibrated against a 10.007 pF standard, designed, constructed and calibrated by the National Standards Laboratories, C.S.I.R.O. (Sydney). The potential was measured by an Avo-8-meter of excellent scale linearity characteristics and calibrated against a precision potentiometer and standard cell.

The 4 MeV linear accelerator incorporates a monitor integrating ionization chamber and a preset dosage control. It was usual to preset 100 r and to read the integrating monitor at the conclusion of the exposure. Ionization charge measured both for the standard chamber and the substituted thimble was related to the integrating monitor reading. When standardizing Victoreens the practice was to use the instrument in the usual way. This was simple and sufficiently accurate for our purposes.

The standard and thimble chambers were placed using the accelerator treatment distance piece (focus chamber distance approximately one metre) as indicated in Fig. 5. As ionization charges, using the 3/16″ and 1/16″ spacers, were closely proportional to the air volume, the instrument was regarded as an extrapolation chamber and the dosage referred to point P. The thimbles were encapsulated in Perspex of O.D. 2.3 cm so that the centre point was $1.15 - 0.78 = 0.37$ cm below P. An adjustment of 0.7 % according to the inverse square law was therefore made to the thimble response, before comparison with the dose rate derived by use of the standard chamber.

Using the collector base of the standard cavity chamber, a perspex annulus of thickness 3/16″ was taken and graphited cellophane stretched over it to give a cavity chamber of wall thickness 2 mg/cm².

An annular spacer was placed on top and absorbing material of various thicknesses added, as in Fig. 6. The ionization response of the chamber was examined for a wall thickness range 0.002 to 2.6 g/cm², giving charge values Q, which could be fitted empirically over the range $0.025 \leq X \leq 2.6$ g/cm² by the formula

$$Q = 1.025 \{\exp(-0.0194\,X) - \exp[-5.16\,(X + 0.05)]\}$$

with high precision. The maximum value of Q occurred for $X = 1.04$ g/cm². Arbitrarily $Q = 1$ for $X = 0.915$ g/cm². Thus the roentgen value r at P for a front window of 0.915 gr/cm² derived using the standard chamber at $T = 22°$ C and $p = 760$ mm is given by

$$r = \frac{1.025}{0.979} \cdot \frac{Q_a}{v} \cdot \frac{3.24}{1\,000} = 3.392 \times 10^{-3}\, Q_a/V$$

when $Q_a \mu\mu$ coulomb is charge measured and v is the air volume.

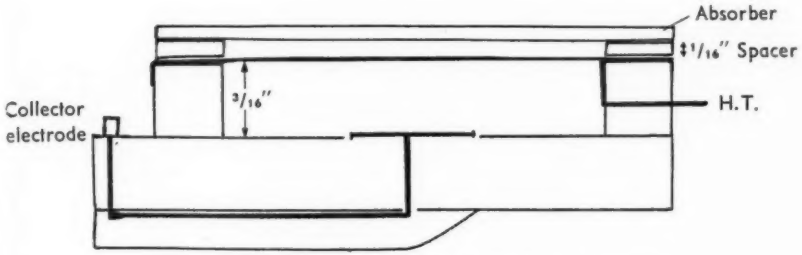

Fig. 6. Extrapolation chamber to examine 'build-up' phenomena.

With a dose rate of 100 r/min (250 p.p.s. each 2 μsec duration) a field strength of 100 volt/cm produced 99 % of saturation charge. No change in ionization current appeared in the range 400 to 1 120 volt/cm so that a field strength of 600 volt/cm was fixed for all work.

The advantages of this type of cavity chamber and the null method of charge measurement are as follows:

1. The air volume may be measured with high precision by the usual metrological procedures.
2. The air volume may be checked by (a) capacitance measurement, (b) extrapolation chamber method, using ionization charge developed by passage of roentgen rays.
3. The electrical field strength between the plates is uniform in the collector area making saturation phenomena relatively uncomplicated.
4. The position of dose measurement is known precisely.
5. The wall absorption correction can be determined precisely.
6. All components irradiated are closely air equivalent.
7. As a null method of charge collection is used with the collector plate protected by a guard ring, changes in cable resistivity due to irradiation, are unimportant.

The standard chamber was checked against an extrapolation chamber of similar design. Agreement was obtained within 2 parts in 1 000 for roentgen value for 100 monitor units.

One interesting fact demonstrated by the use of these two chambers was the difference of registration for positive and negative collection of ions. For the Perspex chamber, positive collection was greater than negative (the difference being of order 2 %), but for the polystyrene extrapolation chamber the negative collection was the greater. The average values of positive and negative collection were taken for dosage calculation. Such average repeated with high precision. The difference between positive and negative collection produced anomalous results when the extrapolation chamber was used with plate separation less than 0.37 mm.

The irradiation of the non-microphonic coaxial cable linking the chamber via a duct with the measuring equipment in the control room gave greater separation of positive and negative values depending on the length of cable irradiated. For standards work such cable irradiation was avoided.

When Victoreen condenser chambers were linked with the Townsend system and irradiated by a 10 × 10 field at 100 cm FCD, there was no detectable difference between positive and negative collection. Using a 10 × 4 field and placing the Victoreen chamber firstly along, and secondly across, the long axis of the field with the thimble at the centre, no stem effect was detected. For the purposes of routine calibration the Victoreen chambers were mounted in place of a back pointer with the axis of the condenser lying along the central roentgen ray and the Perspex cap setup touching the 100 cm distance piece. The correction factor obtained was 1 % greater than that derived with the chamber lying across the field. The lowered response was closely that to be expected from inverse square law considerations.

The condenser chambers behaved well when irradiated with a few hundred roentgens; however, galvanometer drift became marked after the chambers had been subject to several thousand roentgens. The standard chamber was almost free of such defects and the chamber could be switched directly from positive to negative collection without delay due to drift of the galvanometer of the null indication electrometer.

All chambers were supported free in air away from massive objects. A column of polythene (diameter 7.5 cm, and length 50 cm) placed directly beneath the standard chamber enhanced readings by only 1 %. It did not appear likely that back-scatter from the floor formed any significant proportion of the measured dose.

Table 4

The M values

kV const. potential	Added filter mm	HVL mm	Chamber					
			1	2	3	4	5	6
60	Nil	1.63 Al	1.073	1.168	—	0.958	1.082	—
120	Nil	3.0 Al	1.051	1.124	—	0.922	1.057	—
190	Nil	0.26 Cu	1.042	1.110	—	0.898	1.040	—
190	0.5 Cu	1.0 Cu	1.047	1.090	0.929	0.864	1.019	0.99
190	1.0 Cu	1.40 Cu	1.057	1.118	0.941	0.866	1.019	—
190	Thoraeus	2.06 Cu	1.065	1.110	0.977	0.873	1.014	1.010
4 000	Nil	15 Cu	1.108[1]	1.240	1.105[1]	0.882	1.080	1.045
Δ %			4.3	13.0	12.8	0.9	6.6	3.5

1 polystyrene cap, 2 carbon cap, 5 mm wall.

Comparison of quality correction factors

Twelve thimble chambers were examined. Nos. 1, 6, 7, 8, 10 and 12 were Victoreen red bakelite 100 r chambers, Nos. 2 and 4 were Victoreen 50 r black nylon chambers, No. 3 a Victrometer 100 r chamber, No. 5 a Victoreen 100 r red nylon, No. 9 a Victoreen 250 r red bakelite, and No. 11 a Baldwin Farmer (Mark 2) 60 r chamber. The following is a table of M factors derived such that $r = M \cdot n$ where r is roentgens and n is instrument scale registration, and $\triangle$ is the difference between the M values for HVL 15 mm Cu and 2 mm Cu.

Of the twelve chambers examined here, only two behaved badly in terms of an unexpectedly large value of $\triangle$. The $\triangle$ value for No. 2 was quite surprising considering the constancy of M for the HVL range 0.26 to 2 mm Cu. No. 3 behaved somewhat in the fashion of the two chambers examined by the N.B.S., *i. e.* M value increased rapidly with increasing hardness of beam. The behaviour of these chambers indicates the necessity for chamber standardization at all qualities for which they will be used, and that chambers exhibiting increasing values of M with hardening of the roentgen rays beam should be discarded.

Conclusion

For the twelve chambers examined, the mean value of $\triangle$ was 4.7 %, and the mean $\triangle$ excluding chambers 2 and 3 was 3.1 %. However, there is a probability of one in six that this mean value of $\triangle$ will be exceeded by 10 %, so that the policy of accepting M values obtained at 2 Cu HVL. to be valid for supervoltage beams is not recommended. There does not appear to be any substitute for calibration against standard chambers in the supervoltage region.

b e r						N.B.S. values for two 25 r chambers (ref. 8)		
7	8	9	10	11	12	Victoreen HVL in mm	2772	3279
							Stem not irradiated	
—	1.091	0.963	1.076	1.069	1.079	0.23 — 0.32 Cu	1.015	0.980
—	1.078	0.955	1.067	—	1.068	0.5 Cu	1.028	1.000
—	1.061	0.947	1.061	—	1.062			
1.134	1.051	0.929	1.070	1.015	1.060	1.15 Cu	1.040	1.025
—	1.047	0.931	1.068	—	1.061	10.1 — 12.6 Cu	1.135	1.175
—	1.042	0.935	1.073	1.028	1.068			
1.150	1.061	0.974	1.077	1.083	1.091[2]	Δ	9.5	15
1.6	1.9	2.9	0.4	5.5	2.3			

[2] The N. B. S. values have been slightly modified by averaging, but the changes introduced are less than 0.5 %.

Acknowledgements

Our thanks are due to Mr. B. W. Scott of the Bureau of Physical Services, N. S. W to Dr. J. H. Martin of the Cancer Institute Board, Victoria, Mr. D. F. Robertson c the University of Queensland, and to Mr. W. Norgard of the State X-ray laboratory Western Australia, for the loan of ionization chambers for this work.

SUMMARY

Twelve thimble ionization chambers were standardized against a free air chamber i the HVL range 1.6 mm Al to 2 mm Cu and against a standard cavity chamber for HV 15 mm Cu and the respective correction factors are compared.

ZUSAMMENFASSUNG

Zwölf Fingerhutjonisationskammern wurden gegen ein Eichstandgerät im HWS-Gebiet von 1.6 mm Al bis 2 mm Cu und gegen eine Standardjonisationskammer vom Hohlräumstypus für HWS 15 mm Cu standardisiert. Die entsprechenden Korrektionsfaktoren wurden miteinander verglichen.

RÉSUMÉ

Douze chambres (dé-à-coudre) d'ionisation ont été étalonnées par rapport à une chambre à parois d'air dans le domaine des CDA 1.6 mm Al à 2 mm Cu et par rapport à une chambre cavité étalon pour la CDA 15 mm Cu, et les facteurs de correction correspondants ont été comparés.

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RELATIVE EFFECTIVENESS OF TESTICULAR SHIELDING IN DIAGNOSTIC RADIOLOGY

by

P. M. Bretland

The necessity for keeping gonad dosage to a minimum has been emphasised by many authors, notably MARTIN (1956), OSBORN and SMITH (1956) and ARDRAN (1957), and is now well known. The suggestion of CARTER (1958) that the male gonad may be more susceptible than the female (by a factor of 10) emphasises the importance of testicular protection.

A number of techniques for protecting the testes from irradiation have been described, for use where the male gonad is bound to lie in or near the irradiated area. ARDRAN and KEMP (1957) described a 2 mm thick lead shield (mounted on a piece of Perspex) which by interrupting the primary beam reduced the dosage by a factor of at least 25 to 40. A somewhat similar shield of 1.5 mm lead, and 1 mm aluminium supported on lucite and mounted on a stand, is reported by HODGES et coll. (1958) to reduce the primary beam by a factor of 20. ILBERY and SCOTT (1955) mention a 0.5 mm thick lead box which, together with beam filtration, reduced it by a factor of 1 000. MAGNUSSON (1952) using an open-ended nickel-plated brass capsule, obtained a factor of 100. These figures show a wide variation, and it was thought worth while to investigate the part played by scatter from the thighs and pelvis and hence find out

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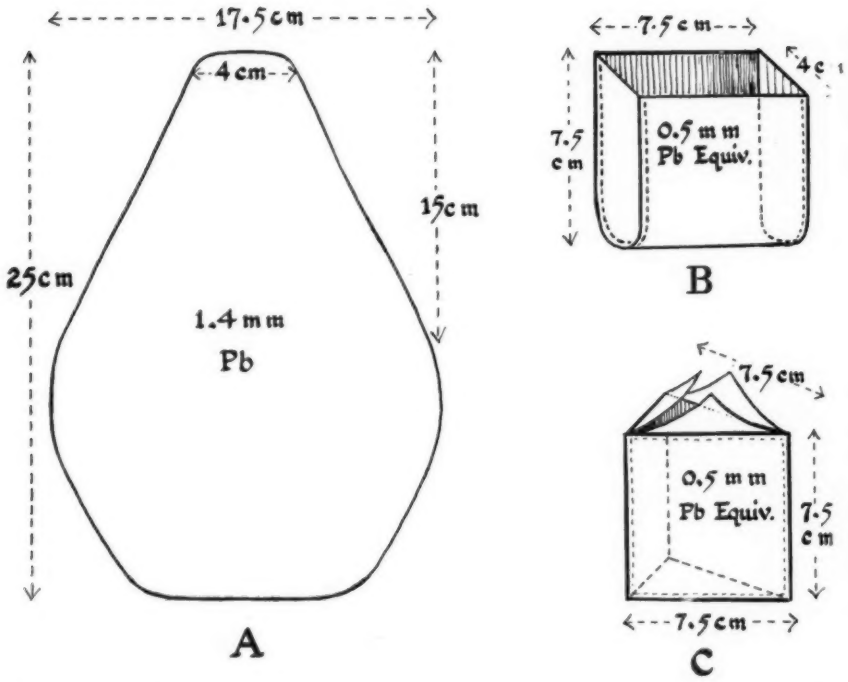

Schematic illustration of the protective devices under test. (The lead rubber strip, which is a rectangular strip of 0.5 mm lead equivalent lead rubber, 40 × 15 cm, is not included in this drawing.)

A — Lead shape, 1.4 mm thick.
B — Open 'Plastoled' box (0.5 mm lead equivalent plastic fabric).
C — Closed 'Plastoled' box (0.5 mm lead equivalent plastic fabric with 0.25 mm lead equivalent upper flaps).

how much advantage might be gained with a device which gave all round protection to the testes. Two such devices, made of a convenient plastic lead-containing fabric were constructed for experimental purposes and compared with two simple shields in current use and with the effects of various projections. (These devices of 'Plastoled' were kindly constructed and made available by Messrs Cuthbert Andrews.)

Materials

The materials used are schematically illustrated in the figure above. Device A, the lead shape (1.4 mm thick) similar to that described by Abram, Wilkinson and Hodson (1958), and a 0.5 mm lead equivalent

lead rubber strip (not illustrated), are both in current use in the University College Hospital X-ray Department, and are designed solely to shield from the primary beam. Devices B ('Plastoled' open box) and C ('Plastoled' closed box) are designed to shield against scatter also; in particular C is provided with upper flexible flaps to shield against scatter from the pelvis.

Method

An air-wall ionisation chamber of about 40 cc (Osborn and Burrows 1958) placed on the front of the scrotum was coupled to a DC amplifier with condenser input (model 1388 A, modified, kindly lent by Messrs Avo Ltd), forming a dosemeter having a wide range of sensitivity. The various protective devices were applied in turn to the ionisation chamber. The dose received from a ward mobile roentgen unit was measured at various kilovoltages and calculated as a percentage of the dose received where no protective device was used, in order to compare the protection afforded by the different devices. These were applied in the following manner.

The 'Plastoled' boxes enclosed the ionisation chamber in front of the scrotum and were in the same position relative to the subject whatever the direction of the primary roentgen beam. The two simple shields were placed on that aspect of the subject nearest the roentgen tube; the lead shape (which was not used in lateral projection), had its apex just below the pubis so as to lie in the subpubic angle without obscuring bone, while the lead rubber strip was merely draped across the thighs, with its upper edge as near to the lower border of the ischial tuberosities as was consistent with covering the scrotum and ionisation chamber. The roentgen set, a Watson Mobilix, was used without added filtration, the inherent filtration of the tube being assumed equivalent to about 0.5 mm aluminium. The half-value layer of the beam was approximately 0.5 mm of aluminium at 53 kV, 0.7 mm at 75 kV and 0.9 mm at 95 kV. A round cone was used giving a field size of about 20 inches (50 cm) diameter at 40 inches (100 cm) and 10 inches (25 cm) at 20 inches (50 cm).

Initial experiments on a phantom of slabs of paraffin wax of appropriate size and shape, to simulate a human body, gave figures somewhat different from those later found to obtain with the body, and thus were of little use. (The amount of scatter greatly exceeded that of the human body, by a factor often greater than four.) All subsequent work was consequently carried out in the post-mortem room as it would obviously be improper to subject the living patient to the exposures required. Most of the work was done on cadavers after autopsy, largely

Table 1

Comparison of the protective effect of various devices at 40 inches FFD under radiographic conditions

	% of primary beam a. p. dose received		
	53 kV	75 kV	95 kV
1. A. p. primary beam			
Lead shape	0.6	1.11	1.59
Lead rubber strip	0.22	0.39	0.58
'Plastoled' open box	1.0	1.33	1.75
'Plastoled' closed box	0.016	0.038	0.2
2. A. p. outside primary beam			
No protection	0.12	0.155	0.19
3. Lateral, primary beam			
No protection	0.6	1.3	2.3
Lead rubber strip	0.12	0.28	0.52
'Plastoled' open box	0.06	0.1	0.16
'Plastoled' closed box	0.002	0.0067	0.038
4. Lateral, outside primary beam			
No protection	0.006	0.012	0.032
5. P. a. primary beam			
No protection	9.1	12.2	13.4
Lead shape	0.13	0.41	0.77
Lead rubber strip	0.07	0.22	0.43
6. P. a. outside primary beam			
No protection	0.036	0.13	0.26

because this was more convenient. A series of observations before and after autopsy was made at an early stage and the differences in the readings rarely exceeded the experimental error estimated at about 5 %.

Measurements were made over the kV range 53 to 95, simulating first radiographic conditions at 40 inches (approx. 100 cm) focus—film distance, (*i. e.* approx. 34 inches or 86 cm focus—skin distance) and then fluoroscopic conditions, *i. e.* 20 inches (approx. 50 cm) focus—skin distance.

The worst case was considered, the primary beam being centred on the scrotum. Where dosage outside the primary beam was measured, the centering was determined by displacing the tube till readings showed clearly that the chamber was outside the primary beam.

Table 2

Comparison of the protective effect under fluoroscopic conditions

	% of primary beam a. p. dose received		
	53 kV	75 kV	95 kV
1. *P. a. primary beam*			
No protection	20.25	25.4	26.5
Lead rubber strip	0.019	0.062	0.21
'Plastoled' closed box	0.0012	0.0039	0.024
2. *P. a. outside primary beam*			
No protection	0.0125	0.054	0.11
3. *P. a. oblique, primary beam*			
No protection	0.31	1.0	1.7
Lead rubber strip	0.0031	0.015	0.065
'Plastoled' closed box	0.0006	0.0019	0.019
4. *P. a. oblique, outside primary beam*			
No protection	0.0012	0.0046	0.013

Results

Radiographic conditions. From Table 1 it is clear that in the anteroposterior projection the 'Plastoled' closed box gives by far the best protection (by a factor of 5 000 to 500), as might be expected, but the 'Plastoled' open box is no better than the lead shape, presumably due to scatter entering the top from the pelvis. The simple 0.5 mm equivalent lead rubber strip is, however, surprisingly effective, keeping the dose at about 0.5 %; it is better than the lead shape, in spite of the latter being of 1.4 mm lead.

In the lateral projection, similar findings apply except that the 'Plastoled' open box is more effective than it is in the anteroposterior, from which it would seem that there is less scatter from the pelvis in this view.

The protective effect of the thighs alone is shown in the posteroanterior projection to be surprisingly good (9 to 13 %), and addition of the lead rubber strip kept the dosage below 0.5 %. With no added protection, outside the primary beam, the dosage did not exceed 0.25 %.

Fluoroscopic conditions. Studies in the anteroposterior projection at 20 inches FSD gave somewhat similar results to those under radiographic conditions. Most fluoroscopy is, however, carried out in the posteroanterior projection; Table 2 shows a comparison between the lead rubber strip and 'Plastoled' closed box and the effects of p. a. and p. a.-oblique projections.

Clearly, even without protection, the p. a. projection is a favourable one and the p. a.-oblique even more so. The lead rubber strip again keeps the dosage well below 0.5 % of the a. p. dose, and the 'Plastoled' closed box again reduces it by a factor of 500 or more. Outside the primary beam the reduction is by a factor of 1 000 in the p. a. and 10 000 in the p. a.-oblique projections, even without protection.

Discussion

These findings are in agreement with those of MAGNUSSON (1952): the 'Plastoled' open box behaves in a somewhat similar way to his capsules. He found, using 1 mm lead, that most of the radiation was due to scatter entering the open end, and thus changed to a thinner material. This has been confirmed by the very small dosages obtained with the 'Plastoled' closed box (which virtually eliminates scatter) made of only 0.5 mm lead equivalent material. It follows that this latter thickness is sufficient to reduce the primary radiation to almost negligible proportions in diagnostic work up to 95 kV.

It is thus only necessary to consider reduction of scatter. Comparison of the lead shape and lead rubber strip shows that it is the device covering the larger area which is the more effective, a not unexpected result; but the lead rubber strip is more effective even than the open box, presumably for the same reason. While the 'Plastoled' closed box is the most effective of all, the lead rubber strip keeps the dosage at or below about 0.5 % of the primary beam dosage.

These figures for simple shields are better than those obtained by ARDRAN and CROOKS (1957) using the shield described by ARDRAN and KEMP (1957). The dosage in the primary beam from the ordinary ward mobile, used in these experiments without added filtration, will include low energy radiation, leaks from the tube, secondary radiation from the cone and air scatter, all of which ARDRAN and CROOKS take great care to exclude, and this (together with the larger area of the lead rubber strip) probably accounts for the difference. It seems likely however, that the conditions studied here are more in keeping with those in many roentgen departments, where such special precautions are not taken.

STANFORD and VANCE (1955) estimate that an a. p. roentgenogram of the pelvis at 65 kV causes a testicular dose of 1 100 mr. The lead rubber strip would reduce this to about 3 mr and the 'Plastoled' closed box to less than 1 mr. Even if the figures were three times as great as these (as appears to obtain in some centres, *e. g.* KOREN and MAUDAL 1957), there does not seem to be an enormous advantage to be gained by the

use of the latter, particularly in view of the difficulty of its application, and since most radiographers in this country are female. It may, however, have an application in a largely male establishment such as a military hospital in cases requiring frequent roentgen examinations to be performed.

Radiation dosage outside the primary beam has been fully studied by HAYBITTLE (1957) using a Presdwood phantom. Although not studied in detail in relation to distance from the edge of the beam, the figures obtained here (included only for completeness and to show that they are about the same as those for simple shields) are not very dissimilar at a distance of a few inches from the edge of the beam. The testicular dose outside the primary beam differs, however, depending on whether the irradiation is a. p., lateral, or p. a., being usually smaller in the two latter even without protection.

Perhaps the most interesting and surprising finding is this effect of the p. a. projection in reducing testicular dosage. It is presumably due to absorption in soft tissue of the low energy radiation. There would seem to be some grounds for performing radiography of the hip joints, pelvis and lumbar spine in the p. a. rather than in the a. p. projection in the male. Fortunately most fluoroscopy is carried out p. a., and with the addition of some suitable shield to eliminate direct testicular irradiation during fluoroscopy the gonad dose is unlikely (with an unfiltered beam) to exceed one per cent of the skin dose received during a fluoroscopic procedure.

The practical value of the observations reported is, on the one hand, to emphasise the importance of simple shielding, provided a large enough area is covered and, on the other hand, to give a sense of proportion to the radiation hazard involved in radiography of the lower part of the male trunk. Broad strips of 0.5 mm lead equivalent lead rubber or 'Plastoled' are readily available in most roentgen departments and with their aid such examinations can be carried out up to 95 kV without the gonad dose exceeding, with an unfiltered beam, one per cent of the primary beam skin dose. The proportion would be greater with a filtered beam, but even if it were twice as much it would still be a very small proportion, practically negligible by comparison with the unprotected dosage.

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SUMMARY

Various methods of testicular protection were compared by means of measurement on the cadaver. A broad strip of 0.5 mm lead equivalent material across the thighs preferably in the p. a. projection, is considered adequate for work up to 95 kV.

ZUSAMMENFASSUNG

Verschiedene Methoden eines Testisschützes werden mit Hilfe von Messungen an Leichen miteinander verglichen. Ein breiter Streifen eines Materiales mit 0.5 mm Bleiäkvivalenz über die Oberschenkel, besonders bei der posterio-anterioren Projektion wird als völlig ausreichend für Spannungen bis zu 95 kV angesehen.

RÉSUMÉ

L'auteur a fait sur le cadavre des mesures comparatives avec différentes méthodes de protection des testicules. Il considère qu'une large bande d'une matière équivalente à 0.5 mm de plomb placée en travers des cuisses, de préférence dans les incidences postéro-antérieures, donne une protection convenable jusqu'à 95 kV.

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FROM THE INSTITUTE OF RADIOPHYSICS (DIRECTOR: PROF. ROLF M. SIEVERT). KING GUSTAF V JUBILEE CLINIC, KAROLINSKA SJUKHUSET, STOCKHOLM, SWEDEN

ATTENUATION OF ROENTGEN RADIATION IN LEAD AT 70 TO 1 400 kV

by

R. Thoraeus

Lead has been used for a long time as the standard reference material for the protective power of other substances. A fairly complete knowledge of the attenuation properties of the standard material is therefore particularly necessary in an institute like this which is charged with the examination of the protection arrangements of the various radiologic installations in Sweden.

In 1930 SIEVERT and THORAEUS published the result of an experimental study of the lead equivalence of numerous materials used in house construction. The attenuation of roentgen radiation of various qualities in the materials, and the corresponding lead equivalents, measured in small irradiated fields by means of a special experimental equipment were described in detail; an account of the data communicated by other authors was also included. Neither the values of the attenuation nor the r-doses behind barriers of the various materials were discussed in that paper; the results may thus be considered as mainly qualitative. It was, however, pointed out that for the effects obtained to be valid for large fields a correction for the influence of scattered radiation might be re-

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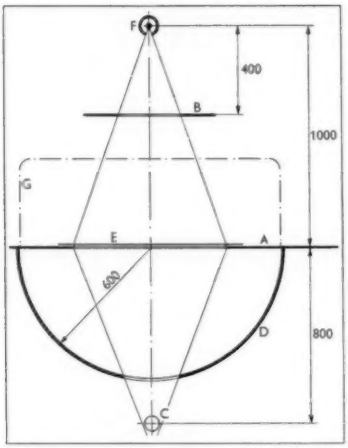

Diagram 1. Plan of the experimental equipment. All measures in mm.

A — Protective wall, *B* — Interchangeable diaphragm, *C* — Ionization chamber, *D* — Protective shield, *E* — Investigation specimen, *F* — Roentgen tube, *G* — Shelf.

quired. From early investigations, for instance by GLOCKER, it is also known that the protective power of a certain thickness of a material depends on the size of the field irradiated.

To supply the roentgen inspection sections of this institute with a detailed knowledge of the protective capacity of lead, an investigation was commenced in the roentgen standard laboratory in 1946; in planning the work attention was first devoted to the conventional range of tube voltages, *i. e.* 70 to 170 kV. The investigation was made by special experimental equipment allowing measurements of the attenuation as a function of the field size irradiated. The radiation was measured free in air by condenser dosemeters of various sensitivity (maximum 2.5×10^{-5} r per volt), the response of which to radiation was stated to have sufficiently small dependence on radiation quality and direction of beam in relation to the ionization chamber (THORAEUS 1951).

The essential parts of the experimental equipment employed are shown in Diagram 1, where *A* is a protective wall containing 4 mm sheet lead and separating the measurement room from the high-voltage room. In this wall an opening, 700 × 700 mm in size, is arranged with its centre about 1.65 m above the floor. The roentgen tube, *F*, has a focus size of about 6 × 6 mm and is positioned with its longitudinal axis vertical at a focal distance of 1 m from the wall, giving a horizontal beam the centre of which is at the same height above floor level.

Table 1

Narrow-beam and broad-beam attenuation and average values of the broad-beam factor t_2/t_1 at tube voltages of 70 to 170 kV

kV	Lead absorber thickness t_1 mm	Small field, 'narrow-beam attenuation'	Large field, 'broad-beam attenuation'	t_2 mm*	t_2/t_1	Average t_2/t_1
70	1	1.3×10^{-4}	1.8×10^{-4}	1.07	1.07	1.07
100	1	2.8×10^{-3}	3.5×10^{-3}	1.07	1.07	
100	2	1.4×10^{-4}	2.2×10^{-4}	2.18	1.09	1.09
100	3	7×10^{-6}	1.6×10^{-5}	3.31	1.10	
125	1	4.5×10^{-3}	6×10^{-3}	1.10	1.10	
125	2	2.4×10^{-4}	4.1×10^{-4}	2.21	1.11	1.10
125	3	1.3×10^{-5}	3.1×10^{-5}	3.32	1.10	
150	1	6×10^{-3}	8×10^{-3}	1.10	1.09	
150	2	3.2×10^{-4}	5.6×10^{-4}	2.21	1.11	1.10
150	3	1.9×10^{-5}	4.2×10^{-5}	3.30	1.10	
170	1	9×10^{-3}	1.1×10^{-2}	1.08	1.08	
170	2	6×10^{-4}	9.3×10^{-4}	2.19	1.10	1.08
170	3	5.1×10^{-5}	8.4×10^{-5}	3.21	1.07	
170	4	4.3×10^{-6}	7.5×10^{-6}	4.24	1.06	

* t_2 = thickness of lead absorber required to give a broad-beam attenuation of the same numerical value as the narrow-beam attenuation of lead absorber thickness in column 2.

The material to be investigated, *E*, is about 800 × 800 mm in size to cover the opening in the wall, *A*, and is positioned close to the latter, as shown in the figure. The size of the field irradiated is fairly accurately defined by interchangeable diaphragms, *B*, of 4 mm lead and positioned at a focal distance of 400 mm. The maximum available diameter of the beam is about two-thirds of the focal distance. This corresponds very nearly to the size of the opening in the wall, *A*, and gives an irradiated area of about 3 600 cm².

A vertical, half-cylindrical protective shield, *D*, lined with 4 mm sheet lead is joined to the wall, *A*, and to both the floor and ceiling of the measurement room in a leak-proof manner. The aperture in the shield may be adjusted by interchangeable diaphragms to such a size that the ionization chamber, *C*, is reached only by radiation from the field irradiated.

The protective power of both lead and various other materials may be investigated by the experimental equipment described. The protective wall is provided with a heavy shelf, *G*, measuring 1 180 × 510 mm to facilitate such investigations. The strength of this shelf is such that a miniature wall of adequate thickness of, for example, concrete or brick-

Table 2

Average values of broad-beam factor t_2/t_1 at tube voltages of 275 to 1 400 kV

kV	275	325	425	525	500	600	800	1 000	1 40
Average t_2/t_1	1.11	1.12	1.11	1.13	1.09	1.11	1.18	1.17	1.2

work can be built up close to the opening in the protective wall, and o a size to overlap the opening, thus allowing measurements of the atten uation as a function of the size of the field irradiated. By such measure ments both the attenuation itself and the lead equivalent of each materia may be obtained.

A large number of experimental measurements were made using plane lead absorbers of different thicknesses, six field diameters from about 10 to 70 cm, and six tube voltages from 70 to 170 kV. It was found that saturation values of the attenuation were only just reached at the maximum available field size of about 3 600 cm² when the greatest lead thicknesses were investigated at the maximum tube voltage of 170 kV. A saturation value was estimated, however, from the slope of the curve plotted.

Some results obtained from the measurements have been collected in Table 1. Comparing the attenuation at minimum field size, narrow-beam, with those at maximum field size, broad-beam, a considerable difference is found. This evidently confirms that the attenuation of a material is not a univocal term. The differentiation necessary to avoid mistakes may be obtained if the terms 'narrow-beam attenuation' and 'broad-beam attenuation' are distinctly used. Particular attention is drawn to the percentage increase of the lead thickness required to reduce the broad-beam attenuation to the same value as the narrow-beam attenuation. At each tube voltage this increase is found to be very nearly independent of the lead thickness, and the average values have therefore been calculated. The ratio t_2/t_1 in the last two columns is the factor by which the lead thickness obtained from the narrow-beam attenuation must be multiplied to obtain the lead thickness which gives the same numerical value of broad-beam attenuation. This ratio may be called the broad-beam factor.

Miller and Kennedy (1955) published the narrow-beam and broad-beam attenuations of 275 to 525 kV roentgen radiation in lead, and Wyckoff, Kennedy and Bradford (1948) the narrow-beam and broad-beam attenuations of 500 to 1 400 kV roentgen radiation in the same material; some values for t_2/t_1 have been calculated from these and collected in Table 2. In Diagram 2, all the values in Tables 1 and 2 have then been plotted against tube voltage. This diagram presents an in-

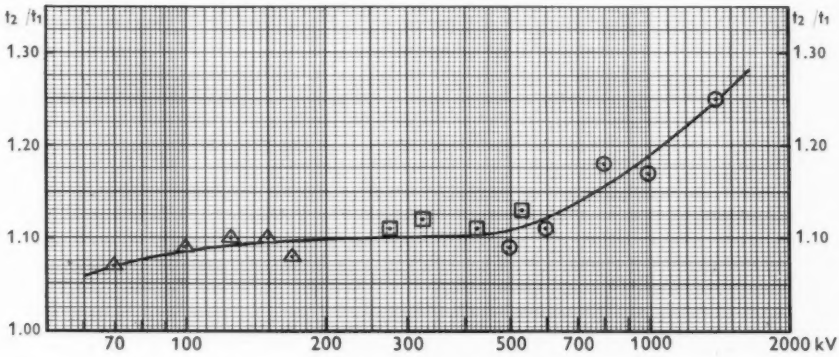

Diagram 2. Broad-beam factor as a function of tube voltage.
△ = values obtained by THORAEUS
⊡ = » » by MILLER and KENNEDY
⊙ = » » by WYCKOFF, KENNEDY and BRADFORD

teresting survey of the broad-beam factor t_2/t_1 as a function of the tube voltage in the wide range from 70 to 1 400 kV. It is seen that (1) the factor is slowly increasing up to 100 kV, (2) the factor may be considered constant and equal to 1.10 in the region 100 to 450 kV, and (3) the factor again begins to increase above 500 kV, reaching a value of about 1.20 at 1 000 kV and 1.25 at 1 400 kV.

Since the narrow-beam attenuation in general is easier to measure experimentally, the factor t_2/t_1 has been defined to refer to that attenuation. The relation between t_2/t_1 and tube voltage, illustrated by Diagram 2, makes it easy to calculate the lead thickness required in a roentgen installation from the known narrow-beam attenuation.

The protection of the personnel and any others in the vicinity of the treatment rooms in radiotherapy departments must primarily be based on considerations of the most penetrating primary beam, corresponding to maximum operating conditions. It is well known that the angle ranges through which the useful beam of a therapy tube can be directed is very wide with most types of container shields. If these ranges are to be freely available, protection corresponding to the maximum operating conditions of the roentgen tube is usually required in the floor, walls and ceiling. The question of scattered radiation from the patient and other problems concerning the influence of the alternative use of lower tube voltages have been discussed in a previous paper (THORAEUS 1950).

If the wide ranges of angle usually accessible can be reduced by a reliable mechanical arrangement, it is correspondingly possible to reduce the amount of protection against the primary radiation. However, in all cases adequate protection is required in the floor and the lower parts

of the walls; only the thickness of the protective material of the ceiling and the upper parts of the walls may be reduced by about 50 per cent corresponding to the necessary protection against the secondary radiation from the patient and any objects irradiated. Such a reduction of the protection will, however, save only the cost of a moderate amount of lead, or of the corresponding equivalent of other protection materials used, and hence result in a relatively small economy. The author has questioned a number of roentgenologists about such an alternative reduction of the adjustment ranges, but none of them would be responsible for such an impairment in the applicability of the installation. The same attitude has also been taken by a number of architects.

SUMMARY

An account of the main results obtained from experimental measurements of the protective power of lead with small and large irradiated fields using tube voltages below 200 kV is given. Similar data for higher tube voltages have been compiled from papers by other authors, and a survey of the region 70 kV to 1 400 kV has thus been obtained.

ZUSAMMENFASSUNG

Ein Bericht über die wesentlichen Ergebnisse, die man aus experimentellen Messungen des Schutzvermögens von Blei bei Bestrahlung von kleinen und grossen Feldern mit Röhrenspannungen unter 200 kV erhielt, wird gegeben. Ähnliche Werte für höhere Röhrenspannungen sind aus den Arbeiten anderer Autoren zusammengestellt worden. Dadurch hat man einen Überblick über das Gebiet von 70 kV bis 1 400 kV erhalten.

RÉSUMÉ

L'auteur présente les principaux résultats de mesures expérimentales du pouvoir protecteur du plomb dans le cas de champs d'irradiation petits et grands avec des voltages inférieurs à 200 kV. Il a réuni les résultats publiés par d'autres auteurs pour des voltages supérieurs, et fournit ainsi une vue d'ensemble pour le domaine de 70 kV à 1 400 kV.

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FROM THE X-RAY LABORATORY OF PHILIPS' GLOEILAMPENFABRIEKEN, EINDHOVEN, HOLLAND

QUALITY AND CHOICE OF POTTER BUCKY GRIDS

I. A new method for the unambiguous determination of the quality of a grid

by

J. G. Bonenkamp and *W. Hondius Boldingh*

Although grids have rendered excellent service in diagnostic radiology since BUCKY published his design in 1913, there is still no definite and generally accepted conception of the specific qualities of these units. When a new type is put on the market, possibly with a higher ratio, new interspacing material or more lines per cm, it is left to the user to determine for himself whether it is better than other types, and for what purposes its use is indicated. The indications of the manufacturer are often concise and do not always make it clear as to what possible disadvantages have to be considered. During the last few years difficulties have also increased due to the tendency to use relatively high voltages — up to 200 kV — in diagnostic radiology, for which various so-called high voltage grids have been marketed.

The user of grids is faced with several problems, for example in deciding in which cases a grid is necessary, whether different grids must be used at different voltages, how the ratio, the lead content, the number of lines

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per cm and the nature of the interspacing material influence the radiographical results, and in which cases the use of a cross grid is to be preferred to a linear grid.

Various methods to solve the problems have been developed but none seems to have proved entirely satisfactory in covering the whole field (SEEMAN 1955, STANFORD 1959). These methods will first be discussed and we shall thereafter describe how it is possible to specify the quality of a grid in an unambiguous manner.

1. Existing methods for determining the quality of grids

In order more easily to express our ideas, we use the following symbols:

Ip = intensity of the primary radiation falling onto a grid

$I'p$ = intensity of the primary radiation transmitted by the grid

Is = intensity of the scattered radiation falling onto the grid

$I's$ = intensity of the scattered radiation transmitted by the grid

$Tp = I'p/Ip$ = transmission of the primary radiation

$V = 1 - Tp$ = loss factor = absorption of the primary radiation

$Ts = I's/Is$ = transmission of the secondary radiation

$\eta = 1 - Ts$ = efficiency = absorption of the secondary radiation

$$B = \frac{Ip + Is}{I'p + I's} = \frac{\text{total incident radiation}}{\text{total transmitted radiation}} = \text{Bucky factor}$$

$$\Sigma = \frac{Tp}{Ts} = \frac{1 - V}{1 - \eta} = \frac{\text{transmitted primary radiation}}{\text{transmitted secondary radiation}} = \text{selectivity}$$

The intensity, I, represents the light output of a calcium tungstate screen, which is measured by means of a photocell (NEMET 1953).

Fig. 1a shows the arrangement by which the sum of the primary and scattered radiation is measured: $Ip + Is$ without a grid and $I'p + I's$ when a grid is present. Fig. 1b shows how the intensities of the primary radiation Ip and $I'p$ are measured. With the aid of the results of these measurements it is possible to calculate the derived quantities Tp, Ts, V, η and B. These quantities are different for different grids. It should be kept in mind that they are no grid constants but functions varying with the voltage on the roentgen tube and the phantom thickness. The measurements must therefore be made for several voltages and phantom thicknesses in the diagnostic range.

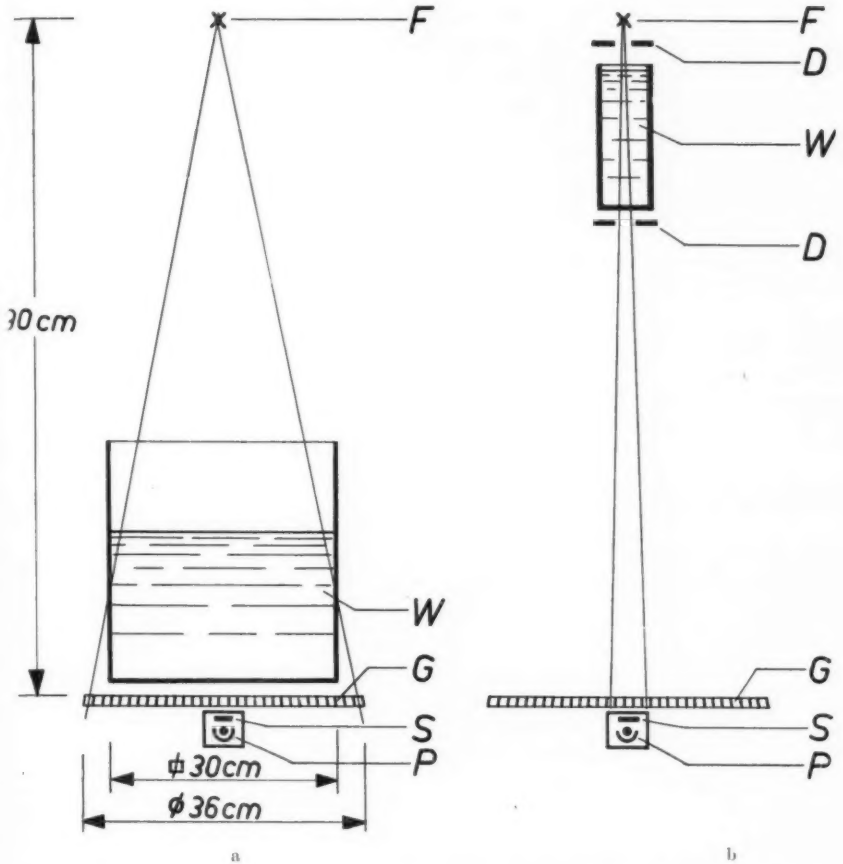

Fig. 1. Measuring arrangement: a) for total radiation, b) for primary radiation only. F — focus, D — diaphragm, W — water phantom, G — grid, S — fluorescent screen, P — photocell.

The use of a photocell to determine the intensity of a calcium tungstate screen instead of a film makes it possible to carry out many measurements in a relatively short time with the effect of increasing the accuracy. It might however introduce a systematic error. Upon investigation, the use of a photocell for determining the derived quantities in which only quotients of intensities occur appeared fully justified. However, in measurements over great ranges of the intensity, such as in the determination of exposure-time-tables certain disturbing effects make it desirable to use a film rather than a photocell. See e. g. subsequent heading (3).

In discussions on grid qualities the quantities mentioned are usually employed. Extensive and fundamental measurements of this kind were carried out as long ago as in 1921 by WILSEY; many others followed his example along the same lines. In the following the customary methods are analysed on the basis of a few examples and the loss factor and the efficiency are calculated.

Example I. Measured at 65 kV, 20 cm water phantom:

Grid A $V = 44\ \%$; $\eta = 92\ \%$
Grid B $V = 51\ \%$; $\eta = 92\ \%$

Both grids absorb 92 % of scattered radiation and are therefore equivalent in this respect. Grid A is to be preferred to grid B due to the smaller absorption of the primary rays.

Such a simple example very rarely occurs in practice. In almost all cases the conditions are such as stated in the following example.

Example II. Measured at 80 kV, 20 cm water phantom:

Grid C $V = 32\ \%$; $\eta = 83\ \%$
Grid D $V = 42\ \%$; $\eta = 93\ \%$

Grid D absorbs more scattered rays than grid C and is therefore better in this respect. On the other hand, grid D also absorbs more primary rays, which, in fact, is unfavourable. In this normal example it is not readily clear which grid is to be preferred. The influence of V and η must be weighed against each other. For this purpose it is customary to calculate selectivity Σ (DE WAARD). $\Sigma = \dfrac{1 - V}{1 - \eta}$ is greater as V is smaller (so favourable) and η greater (likewise favourable), in other words, a good grid has a large Σ.

If we apply this to example I, we find that

$$\Sigma_A = \frac{100 - 44}{100 - 92} = 7.0 \text{ and } \Sigma_B = \frac{100 - 51}{100 - 92} = 6.1$$

We already knew that grid A is better than grid B and this indeed is in accordance with the greater value of Σ.

Applied to example II we find the $\Sigma_C = \dfrac{100 - 32}{100 - 83} = 4.0$ and $\Sigma_D = \dfrac{100 - 42}{100 - 93} = 8.3$, so grid D is superior to grid C if the selectivity is considered to be a correct standard. However, this is not the case, as is shown by the following simulated example.

Example III. Grid E transmits 60 % of the primary rays and 20 % of the scattered rays, consequently $V = 40\ \%$; $\eta = 80\ \%$; $\Sigma = \dfrac{60}{20} = 3$.

Grid F transmits 30 % of the primary rays and 10 % of the scattered rays, consequently $V = 70\ \%$; $\eta = 90\ \%$; $\Sigma = \dfrac{30}{10} = 3$.

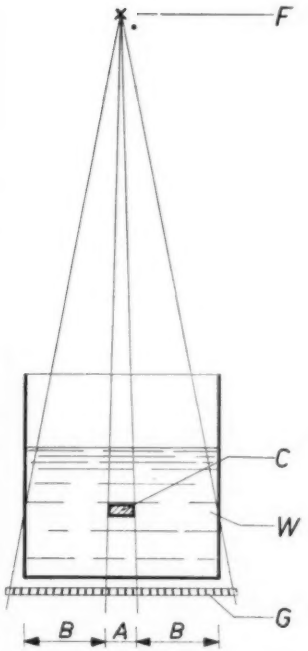

Fig. 2. Water phantom with contrast object C.

According to the standard of the selectivity both grids are equal in quality. This is indeed true with regard to the improvement in contrast of the grids, for the ratio of the primary rays to the secondary rays which spoil the contrast is the same for both grids. However, as grid *F* has twice as large a Bucky factor and consequently requires twice as long exposure times as grid *E*, the grids will not be considered to be equivalent and grid *E* will be preferred.

Summarizing, we can conclude that only in exceptional cases, as in Example I, will it be sufficient to consider V and η.

Some doubt remains in normal cases. Selectivity alone is not a good quality factor, because it does not cover the desirability of small exposure energies.

2. Improvement in contrast by means of grids

Before dealing with the value of small exposure energies the contrast improving capacity of a grid will be examined first. Fig. 2 shows a water phantom containing a contrast producing object, e. g. a disk of aluminium having a thickness d.

Due to the different absorption coefficients $\mu_{al} = \mu_2$ and $\mu_{water} = \mu_1$ the intensity of the primary rays is different after passing through the aluminium, Ip_2 (area A), and through the surrounding water, Ip_1 (area B in Fig. 2). For the ratio of these intensities one can write

$$\frac{Ip_1}{Ip_2} = \frac{e^{-\mu_1 d}}{e^{-\mu_2 d}} = e^{(\mu_2 - \mu_1) d}$$

If the intensity of the scattered radiation is neglected we find for the density in the straight part of the film-density curve that

$D = \gamma \log Ip + \text{const.}$, in which γ = gradation of the film.

For the difference in density under the aluminium and its surroundings we can then write

$$Cp = \text{primary contrast} = D_1 - D_2 = \gamma \log \frac{Ip_1}{Ip_2} = \frac{\gamma}{c} (\mu_2 - \mu_1)\ d =$$

$$\frac{\gamma}{c} (\mu_{al} - \mu_{water})\ d, \text{ in which } c = \ln 10.$$

For an air bubble in water instead of aluminium

$$Cp = D_2 - D_1 = \frac{\gamma}{c}\,(\mu_{water} - \mu_{air})\,d = \frac{\gamma}{c}\,\mu_{water}\,d,$$

because μ_{air} is negligible. Both $\mu_{al} - \mu_{water}$ and μ_{water} decrease with increasing voltage and so does likewise Cp. However, the actual contrast is smaller than Cp owing to the influence of the scattered radiation. If the area of the contrast producing object is small with respect to its distance from the film, as e.g. in the arrangement of Fig. 2, the scattered radiation behind the object is just as intensive as behind its surroundings and it can be proved then that

$$\Delta D = D_2 - D_1 = \frac{Cp}{1 + \dfrac{Is}{Ip}} = C_o \text{ (MORGAN 1945)} \qquad (1)$$

In a few favourable cases $\dfrac{Is}{Ip} \ll 1$ so that $\Delta D \sim Cp$. The value of Is/Ip increases with the beam diameter, the thickness of the scattering material, and also with the voltage, up to some 100 kV; at higher voltages this value slightly decreases. Despite the slight decrease of $\dfrac{Is}{Ip}$ above 100 kV the contrast further decreases, because the influence of the decreasing factor Cp more than compensates that slight effect.

After these considerations we can express the improvement in contrast due to a grid by a simple formula. If one works without a grid, the contrast will be expressed by the formula (1); the use of a grid has no influence on Cp if we keep to the same voltage as that with no grid, but Is/Ip must now be replaced in the formula by $I's/I'p$. The factor by which the contrast is improved from C_o to C is thus

$$\frac{C}{C_o} = \frac{\Delta D' \text{ (with grid)}}{\Delta D \text{ (without grid)}} = \frac{1 + Is/Ip}{1 + I's/I'p} \qquad (2)$$

In the exceptional case in which both Is/Ip and $I's/I'p$ are $\gg 1$, we may write

$$\frac{1 + Is/Ip}{1 + I's/I'p} \simeq \frac{Is/Ip}{I's/I'p} = \frac{I'p/Ip}{I's/Is} = \Sigma = \text{selectivity}$$

However, generally speaking, $I's/I'p \lesssim 1$, so that the neglection is not permitted. It is therefore better not to use the selectivity as a measure

of contrast but the factor from (2), which we shall call the contrast factor C/C_o.

We can also express C/C_o in the other grid quantities, viz.

$$\frac{C}{C_o} = \frac{1 + Is/Ip}{1 + I's/I'p} = \frac{I'p}{Ip} \cdot \frac{Ip + Is}{I'p + I's} = Tp \times B \qquad (3)$$

or in words:

contrast improvement at a certain voltage = primary transmission × Bucky factor.

3. The required exposure energy

For water thicknesses of 10, 20 and 30 cm. Diagram 1, a) to c) show, as a function of the voltage, the times required for making an exposure with density 1.0, using calcium tungstate intensifying screens of average speed and with a roentgen film of average sensitivity which was developed up to $\gamma = 2$. The tube current is chosen inversely proportional to the voltage so as to maintain a tube load of 4 kW (isowatt).

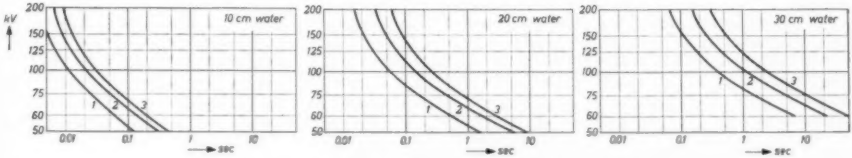

Diagram. 1. Exposure times required for an exposure with density 1.0. Calcium tungstate intensifying screens and film both of average sensitivity. Tube load 4 kW.

1 — without grid, 2 — with lightest grid, 3 — with heaviest grid.

The extra filter in the roentgen tube was 0.5 mm Al + 0.05 mm Cu throughout the voltage range. The choice of this filter will be discussed later. (The roentgen tube used was an experimental 200 kV tube with an inherent filter of 2 mm Al.)

Each figure contains 3 lines; the line most to the left refers to the measurements without grid. The other two lines represent two grids from a series of 13 which were measured by us. The two grids are extremes as regards absorption, so that each of the other 11 grids is represented by a line which lies somewhere between these two lines.

In the horizontal direction it is possible to compute in these figures by what factor, at a given voltage and corresponding tube current, the times are multiplied when a grid is used, as compared with the employment of no grid. This factor is the Bucky factor $B = \frac{Ip + Is}{I'p + I's}$ which in-

dicates by what factor the grid reduces the total incident intensity at a given voltage.

At the same time it is possible to read off along the vertical lines to what extent the voltage has to be increased when a grid is used, as compared with the employment of no grid, if the exposure time and the tube load are kept constant.

This voltage increase varies for different grids and is greater as B is greater, which is also seen from the diagrams.

4. The criterion for the quality of grids

Under heading (2) we have seen that, with the voltage remaining the same, a grid improves the contrast by the factor $C/C_o = Tp \times B$. However the exposure time will then have to be increased by the factor B, which results in a proportionately greater tube loading and heavier dose to the patient. In practice a (favourable) large C/C_o is nearly always accompanied by an (unfavourable) large B. To decide which grid is the best in practical work, we compensate the Bucky factor by increasing the voltage, as was explained under heading (3). As a higher voltage is accompanied by a decrease in contrast the gain $C/C_o = Tp \times B$ (which is obtained with the voltage remaining the same at the expense of a longer exposure time) is partly lost.

Our criterion is now as follows:

> of two grids the better one gives the greater contrast at the same density, tube load, and exposure-time, irrespective of the required voltage.

It was already explained that a greater C/C_o is, as a rule, accompanied by a larger B and therefore requires a larger increase in voltage. This will result in a greater loss of the greater initial gain in contrast. By means of measurements it is possible to ascertain the remaining gains in contrast, and hence which grid is the best.

5. Application of the criterion

Measurements have been carried out by us with 13 different grids with voltages ranging between 50 and 200 kV and with 3 different water phantom thicknesses, viz 10, 20 and 30 cm, each time with two contrast objects, viz aluminium and air. To make the effect of these grids on the contrast as marked as possible, we always used a wide beam, viz 36 cm

Ø which is comparable with 30 × 40 cm, at a focus distance of 90 cm, and gives rise to a fairly large amount of scattered radiation. From these measurements we shall first give an example, namely the case of a 20 cm water phantom with a contrast object of 2 mm Al at its centre. The measuring arrangement is shown in Fig. 2.

With the aid of a multiplier photocell the light output of a calcium tungstate screen is measured under the aluminium and by the side of it; the value I_1 and I_2 are then found (without using a grid).

With the aid of these numbers $\Delta D = \gamma \log \frac{I_1}{I_2}$ is calculated, whereby the gradation is assumed to be $\gamma = 2$. (The measurement of contrast is fundamental for these considerations. A photographic control has shown that a photocell gives reliable results also for contrast measurements.) It appears from what is said under heading (2) that the contrast ΔD is a decreasing function of the voltage. All other conditions remaining unchanged, the contrast with the given measuring arrangement is fixed unequivocally by the voltage. This also applies to the exposure time which gives $D = 1.0$ and which can be found in Diagram 1.

The contrasts without a grid can then be plotted as a function of the exposure time, with the voltage as a parameter. This is done in Diagram 2 in which the bottom line is the result of the measurements just mentioned.

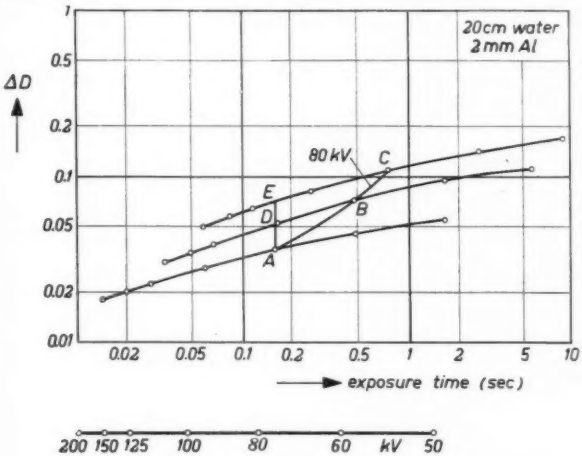

Diagram 2. Contrast ΔD as a function of exposure time (4 kW d. c.), density 1.0, gradation 2.0, from 50 to 200 kV. Bottom curve — no grid, second curve — lightest grid, top curve — heaviest grid. A, B, C are points of equal voltage, 80 kV. A, D, E are points of equal exposure time.

To find the characteristic line of a certain grid one has to know the contrast $\Delta D'$ and exposure time t', relating to that grid, with equal density and tube load. For each voltage these can be calculated from the values of Tp and B for the grid with the aid of the formula

$\Delta D' = C/C_o \times \Delta D = Tp \times B \times \Delta D$ formulas (2) and (3)

and the formula $t' = B \times t$ that follows from the definition of B. Therefore it is not necessary to measure explicitly the contrasts and exposure times for each grid, but it is sufficient to measure the values of Tp and B in the way explained under heading (1).

Starting, for example, from an exposure at 80 kV without grid (point A), we get an increase in exposure time and contrast if we use, likewise at 80 kV, two different grids (points B and C, which we call *grid 1* and *grid 2*, respectively. To apply the criterion, one has to compensate the Bucky factor by increasing the voltage for each grid. In Diagram 2 this means following the grid lines to the left as far as points D and E, which lie perpendicularly above A and have therefore the same exposure time. The ultimate gain in contrast AD and AE, respectively, is then somewhat smaller than the original gain (points B and C). We see that *grid 2* gives more contrast with the same exposure time. *Grid 2* is the better of the two grids throughout the voltage range, because its line is always found to lie above the line for *grid 1*.

The fact that the grid lines do not intersect is of great importance, because it means that, as far as its contrast improving effects are concerned, the grid which is situated highest, is to be preferred to the other throughout the voltage range.

As will be shown in detail in part II of this article it appears that, with one minor exception, which we shall discuss later on, the fact that the quality lines obtained for different grids in the way mentioned above do not intersect, is not only independent of the voltage, but also of the thickness of the phantom and the nature of the contrast object and that the location of the quality line is, therefore, a characteristic property of the grid, which is independent of the exposure conditions. This point will be dealt with in more detail in a subsequent article.

SUMMARY

Existing methods for grid examination give insufficient information for an unambiguous qualification. A new criterion of quality based on the improvement in contrast and obtained when the exposure energy is kept constant, due to an adequate choice of voltage, is suggested. It is explained how this criterion can be applied graphically by drawing a curve representing the contrast as a function of the exposure time under standard conditions. As regards the contrast improving effect, the line lying highest then corresponds to the best grid.

ZUSAMMENFASSUNG

Untersuchungen des Rasters mit den zur Zeit vorliegenden Methoden geben unzureichende Informationen für eine unzweideutige Beurteilung seiner Qualität. Ein neues Kriterium wird vorgeschlagen, das auf Kontrastverbesserung basiert ist und das man

erhält, wenn die Belichtungsenergie durch geeignete Kilovoltwahl konstant gehalten wird. Es wird erklärt, wie dieses Kriterium graphisch angewendet werden kann mit Hilfe einer Kurve, die den Kontrast als Funktion der Belichtungszeit unter Standardbedingungen darstellt. Bezüglich der kontrastverbessernden Wirkung entspricht demnach die höchstgelegene Kurve dem besten Raster.

RÉSUMÉ

Les méthodes existantes d'examen des grilles fournissent des données insuffisantes pour une qualification sans ambiguïté. Les auteurs proposent un nouveau critère de qualité basé sur l'amélioration du contraste obtenu quand l'énergie d'exposition est maintenue constante, grâce à un choix adéquat du voltage. Ils expliquent comment on peut appliquer graphiquement ce critère, en traçant une courbe représentant le contraste en fonction du temps d'exposition dans des conditions standard. La ligne située le plus haut correspond à la grille qui a le meilleur effet d'amélioration du contraste.

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BOOK REVIEWS

TIME-DOSE RELATIONSHIP AND MORPHOLOGY OF DELAYED RADIATION LESIONS OF THE BRAIN IN RABBITS. By Nils O. Berg and Martin Lindgren. 118 p., 72 figs, 19 tables. Acta radiol. Suppl. 167 (1958). Sw. Kr. 30: —.

Investigations of the tolerance of the human skin to irradiation have made it possible to construct time-dose relationship curves for this tissue. Compared with the importance of such knowledge, only few investigations have been made of the time-dose relationships for the tolerance of other tissues. This experimental investigation was planned to determine some time-dose relationships for delayed radiation lesions in the rabbit.

Delayed radiation lesions in the brain and the skin, as well as the ear and skull, were studied in 89 rabbits after two types of daily fractionated roentgen irradiation (12 and 30 days respectively) as well as after a single exposure to the right half of the rabbit's head. The irradiation data were: 200 kV, HVL 0.93 mm Cu, FSD 25 cm, field size 30×40 mm.

The brain lesions were plotted in diagrams of sections through the brain and the conditions for exact dosimetry in the lesions were studied. The distribution and morphology of the lesions is extensively illustrated.

Neurologic signs, mainly vestibulo-cerebellar, were noted, their latency decreased with increasing dose. The relationships between the signs and the intra-cerebral as well as extra-cerebral lesions were recorded. The vestibulo-cerebellar signs were found to be due to damage to the labyrinth as well as to the cerebellum and nerves from the pons. The labyrinthine lesions were more common after fractionated irradiation than after single dose exposures. In a few animals irradiation was followed by the development of sarcoma of the bone of the skull. Inflammatory reactions in the brain were seldom seen; they were due to spontaneous encephalitis or complicating suppurative skin necrosis or otitis. The uncomplicated delayed radiation lesions in the brain did not include infiltration of lymphocytes and plasmocytes.

Various types of radiation lesions in the brain are recorded and include frank necrosis, partial destructions of white and grey matter as well as profound glio-vascular alterations; as a rule they were seen in combination. Direct vascular damage, such as haemorrhages and teleangiectasis, and fibrinoid necrosis of vessel walls was often observed as a solitary lesion in otherwise undamaged brain tissue. Frank radionecrosis following single dose exposures and fractionated irradiation were seen mainly in the white matter. More discrete injuries, usually of vascular origin, showed the same predilection for the white matter. The distribution of these lesions in different areas of the brain are tabulated. The morphologic analysis supports the assumption that the vascular changes were essentially primary.

Delayed radiation lesions in the brain were found to be of essentially the same types after fractionated irradiation as after single dose exposures. This permitted the construction of time-dose relationship curves for cerebral radionecrosis and discrete lesions including damage following single exposures. The slopes of the curves for the different types of lesions were essentially the same (0.34). Time-dose relationship curves for the different skin reactions observed (permanent epilation, atrophy, and skin necrosis) showed the slope to be 0.33 to 0.34. The similarity in the slope of the time-dose relationship for delayed radiation lesions in the brain and the skin might be due to a common 'substrate' for these types of injuries. Judging from the morphologic observations, this substrate probably consists of the structural elements of the vessels. This would imply that the slope of the time-dose relationship curves should be the same for the tolerance of the skin as of the brain in a given animal. This experimental investigation thus gave information on the nature of the tolerance of tissues to fractionated irradiation in rabbits, which could be directly applied to the human tissues. The lowest focal unfractionated dose that produced brain necrosis was found to be about 1 700 r and the smallest dose followed by radiation lesions in the brain was calculated to be about 1 200 r. The pathogenesis of the brain lesions is briefly discussed.

Autoreview

THE RADIATION REACTION IN THE VAGINAL SMEAR AND ITS PROGNOSTIC SIGNIFICANCE. By Olle Kjellgren. 170 pages, 72 illustrations, 39 tables, 12 colour plates. Acta radiol. Suppl. 168 (1958). Sw. Kr. 35: —.

The literature on gynecological exfoliative cytology, especially radiation cytology, is surveyed. Two-hundred and eighty-seven patients with cervical cancer treated according to the Stockholm method were studied. Factors thought capable of influencing the radiation reaction in the vaginal smear were analyzed and the prognostic significance of the radiation reaction was studied. The patients were classified as showing good or poor response to radiation with 60 % benign exfoliated cells changed by radiation as a dividing line.

There was no evidence suggesting that the response was influenced by international stage, duration of history, number of pregnancies, gross tumor type or radium dose within therapeutic limits. It was found that the radiation reaction is correlated with menopausal state, with hormonal activity in the pretreatment smear and with the age of the patient.

Analysis of the prognostic significance of the radiation reaction showed that the five year apparent recovery rate, the primary local healing rate, and the local five year healing rate were significantly higher in the good response group. The local recurrence rate was significantly higher in the poor response group. No difference was found in the metastasis rate between the poor and good response groups with local healing. Radiation injuries were about three times more frequent in the good than in the poor response group.

Autoreview

On Tolerance of Brain Tissue and Sensitivity of Brain Tumours to Irradiation. By Martin Lindgren. 73 pages, 38 illustrations. Acta radiol. (1958). Suppl. No. 170. Sw. Kr. 25: —.

Our knowledge of the tolerance of human brain tissue to roentgen irradiation has proved insufficient. Experimental and clinical data available in the literature are vague and by no means precise enough to serve as a reliable basis in planning of the treatment. Adequate radiotherapy requires knowledge of the tolerance of normal brain tissue and of the radiosensitivity of various brain tumours as well as the time-dose relationships for the reactions.

In this investigation an analysis of the influence of roentgen rays was made from the findings in 71 autopsy cases; the findings in 18 of these cases are documented in detail and discussed.

Necrosis in otherwise healthy tissue in the occipital lobe was found in 4 cases with primary tumours of the cerebellum.

Preliminary time-dose relationship curves were calculated for radionecrosis in human brain from 13 cases in the literature and 4 personal cases. The slope of the curve in relation to the x-axis in a log/log diagram was 0.26. The slope of the curve and the level of dosage required to produce necrosis is discussed. The minimal dose in the present material that produced necrosis on delivery of rays through medium-sized fields was between 4 500 and 5 000 r/30 days.

Repair after irradiation of the primary tumour in 4 cases of medulloblastoma and in 1 case of ependymoma was verified histologically. No necrosis in the bed of the tumour, *i. e.* in the healthy tissue immediately surrounding the tumour, was ever observed. All the patients died from metastases. Complete destruction of the primary tumour and simultaneous destruction of surrounding tissue not infiltrated with tumour were observed in 2 cases of glioblastoma and in 1 case of astrocytoma of intermediate type, in 1 case of medulloblastoma, and in 1 case of pinealoma. Massive necrosis within and beyond the tumour region was observed in 1 case of glioblastoma, in 2 of astrocytoma of intermediate type, in 2 of astrocytoma, and in 1 of malignant ependymoma.

It is concluded that the tolerance limit can be respected in the roentgen treatment of radiosensitive tumours such as medulloblastoma and ependymoma. In the treatment of tumours belonging to the astrocytoma group, however, this limit must be exceeded.

Autoreview

Slipping Epiphysis of the Hip. A roentgenological and clinical study based on a new roentgen technique. By Lars Billing and Erik Severin. 76 pages and 39 illustrations. Acta radiol. Suppl. 174 (1959). Sw. Kr. 35: —.

The epiphyseal plate of the adolescent femoral head is shaped like the glass of a watch and when the femoral epiphysis slips, the plane on which it lies slopes backwards. The most reliable way to measure how far the epiphysis has moved is to measure the slope of this plane, which the authors call the epiphyseal cartilage plane. The authors describe a simple and exact roentgenographic technique by which this may be done. The films obtained are also excellent for judging the condition of the femoral head and neck, the projection of the former always being constant from one examination to another.

The authors employed the technique in a series of 63 cases of slipped femoral epiphysis. Both hips were examined repeatedly throughout the adolescent years of the subjects, and several important observations were made. A minor slip of the epiphysis may be detected in the roentgenogram by measuring the slope of the epiphyseal cartilage plane and by looking for signs of remoulding of the neck. Thus slipping in the contralateral healthy femoral epiphysis was detected in several cases of the authors' series before the patients themselves experienced any symptoms in the joint.

The course of the condition after nailing was studied with special reference to the time at which the epiphyseal cartilage ossified, the way the femoral neck was remoulded, and the extent to which the head and neck were deformed at the end of adolescence. It was observed that the time the slipping started was more correlated to the maturity of the skeleton than to the age of the patient.

From the results of this study, the authors are now able to judge how great a risk there is that slipping of an apparently healthy femoral epiphysis occurs in a hip contralateral to one in which this condition exists.

The indications for nailing are discussed in the light of the knowledge gained from this investigation and preventive nailing is recommended in certain cases; a simple technique for its performance and for roentgen control at operation is described.

The authors consider the new technique to be essential for the proper diagnosis and treatment of slipped femoral epiphysis.

Autoreview

La Broncografia. By L. Di Guglielmo, L. Pigorini, and G. A. Citroni. 674 pages, 621 illustrations. 'Il Pensiero Scientifico', Editore, Roma 1957. Lire 15.000.

This book by two radiologists and an ENT specialist is based on over four thousand bronchographies performed over a period of several years at the Forlanini Institute in Rome and at the Roentgenologic Institute and the ENT Clinic of the University of Pavia.

The volume is divided into three parts and forty-six chapters. Part 1 (135 pages) covers the bronchographic technique and the anatomy and physiology of the bronchi. Part 2 (83 pages) deals with those bronchographic changes which may be common in different conditions, such as alterations in the lumen, contour, and position, of the bronchi. Findings related to the presence of parenchymal cavities and extrinsic compression of the bronchi are also analyzed. Part 3 (455 pages) is devoted to bronchography in diseases of the bronchopulmonary system and of the chest in general. Along with the findings in bronchopulmonary malformations, specific and aspecific inflammatory processes, and benign and malignant neoplasms, in conditions such as asthma, emphysema, echinococcus, pneumoconiosis, foreign bodies, bronchial trauma, and fistulae, are dealt with in detail. The final chapters are concerned with diseases of the mediastinum, pleurae, the diaphragm and chest wall, including post-operative appearances following surgery of the lung or chest wall or an artificial pneumothorax. A chapter deals with parenchymal lesions following radiation.

Copious references, probably the most extensive ever collected on this subject in a single volume, are included at the end of each chapter.

Francesco S. Tolone

LEITFADEN DES STRAHLENSCHUTZES FÜR NATURWISSENSCHAFTER, TECHNIKER UND MEDIZINER. Von Hans R. Beck, Hans Dresel und Hans Joachim Melching. 253 Seiten, 100 Abbildungen und 19 Tabellen. Georg Thieme Verlag, Stuttgart 1958. D. M. 36.

According to the publishers' note this book is intended to offer basic information on irradiation protection in the widest sense to scientific, medical and technical readers as well as to laymen in various administrative and political positions. This means that the subject matter should be understood by those without special training and, as the 225 pages must cover the whole field, it means moreover that each particular subject can only be broadly covered. It is always a matter of opinion as to what material should go into such a book and as to what should be particularly emphasized. The reviewer's feeling is that the authors have produced a well outlined survey. Any reader who likes to have more detailed information in a particular field can obtain this through the references.

Some historical data on radiation lesions in the early days of roentgen and radium work as well as the development of regulations and laws in radiation protection are contained in the first chapter.

The physical properties and the interaction of ionizing radiation with matter, the classical concepts of the atomic structure, atomic particles and radioactive isotopes, and similar basic principles are given in a clear and simple form. Only elementary mathematics are used in formulas and numerical calculations, but roentgen rays and neutrons and their dosimetry are treated more fully. The chapters on physics conclude with data on cosmic and background radiation.

In the biological sections the authors survey subjects such as the target theory and radiochemical processes with which it is necessary to be familiar in order to understand the mechanism of the biologic effects of radiation. These effects are further discussed as a function of ionizing density, dose and dose distribution, oxygen concentration in the tissues, and other factors. The radiation lesions of the human organism form the subject of a special chapter although experimental work on animals are also interposed in the text. It would, perhaps, have been better if all the experimental material had been gathered in a single section. In the 'human' chapter, for example, research on the effects of long-term, low-dose-level irradiations on laboratory animals is also discussed, and, as the results seem in part contradictory they are difficult to evaluate as regards their importance in the human race. In the same section, the incorporation of radioactive material in the body, *e. g.* from 'fall out', is discussed. More weight should have been given to Sr^{90}, which is only incidentally mentioned, whereas J^{131} is treated at some length. Then follow data on the genetic effects on *Drosophila* and the mouse, and their implications for man, as well as radiation lesions in the foetal stage; in this connection one would have welcomed more emphasis on the relatively recent and important contributions of Russel, as these beyond doubt cover the most extensive mouse material.

After a section on the radiation exposure of man from various sources the authors proceed to treat the subject of 'protection' in the physico-technical as well as the biologico-medical sense. Practical applications of the methods to indicate and measure radiation, activity determinations in contaminated water, and incorporated activity in plants, animals, etc are discussed. In the biologico-medical chapter the principles of the most important protective substance, e. g. SH-compounds are given and conventional therapeutic methods are described.

The last chapter is devoted to organisation problems and measurements with the possibilities in mind of catastrophies due to accidents in reactors or to atomic warfare.

Arne Forssberg

PNEUMOENCEPHALOGRAPHY. By E. Graeme Robertson. 482 pp., 209 figs., 34 plates. Charles C. Thomas, Springfield, Ill., 1957. $ 14.50.

This comprehensive work is based on long personal experiences with pneumoencephalography, to the development of which the author has made many valuable contributions. His earlier publications, back to "Encephalography" (1941), are incorporated.

In the first part of the book a very detailed description is given of the distribution of gas and the mechanism of ventricular filling including extensive experiments with glass models of the ventricular system and subarachnoid space and their practical application. The presentation is interesting and the chapter on the failure to obtain ventricular filling and its rectification is of particular value. The encephalographic technique is described at length. The author recommends the use of two needles, one for the injection of gas and another for evacuating fluid and measuring the pressure by a manometer; in the reviewer's opinion it is better to employ a single needle, adapted for the alternate injection of gas and the tapping of fluid under slight pressure, as a more simple and safe method. In the recumbent position it is an advantage to take lateral views of all parts of the ventricles with a horizontal beam when the head is still in position for the antero-posterior and postero-anterior films instead of obtaining them after the head is turned with one side uppermost, as the author recommends.

The main part of the book consists of separate chapters on the posterior fossa, the aqueduct of sylvius, the third ventricle and neighbouring cisterns, and the lateral ventricles. In each section a description is first given of the roentgenographic anatomy and then of displacement and deformation by space-occupying lesions. The section on tumours in the posterior fossa is relatively small, which may probably be ascribed to the fact that the author avoids encephalography when the intracranial pressure is raised, owing to the risks involved. However, with the injection of only small amounts of gas without withdrawal of fluid the examination may be performed without undue risk.

Some chapters on atrophic lesions, vascular diseases, injuries to the head, infections and hydrocephalus, are followed by one on encephalography in childhood and finally an instructive chapter on developmental abnormalities.

The book is richly illustrated and the reproductions of the roentgenograms are of high quality throughout. The excellent tracings which are added to most of the figures facilitate the interpretation and a series of coloured plates gives a particularly good conception of the normal anatomy of the cisterns.

F. Olov Löfgren

ROTATION RADIOGRAPHY. By Shinji Takahashi. 164 pages, 118 illustrations, 19 tables. Japan Society for the Promotion of Science. Maruzen Co., Tokyo 1957.

The author describes a number of different techniques for which he uses the general term 'rotation radiography'. These are based either on rotation of the patient's body in the roentgen beam, or rotation of the tube and film around the stationary patient.

One of the first methods devised by the author was to take a great number of conventional roentgenograms while the tube was moved step by step through at least 190° around the patient. In this way an organ is roentgenographed from almost all possible angles and its three-dimensional structure deduced. If a sufficient number of films are obtained, it is even possible to plot various cross-sections of the organ on drawing paper by geometric construction.

Methods were then developed with the roentgen rays passing through a horizontal slit to a vertically moving film while the patient was rotated in the beam. The resultant film is called a continuous rotatogram and requires special roentgenologic experience for its interpretation. However, it is possible to construct the actual cross-section photographically from this film by a special apparatus; this cross-section may be regarded as a transversal planigram in which the angle between the film and roentgen beam is zero.

Among other methods developed to obtain cross-sections of the body, one is identical in principle with the technique of transversal planigraphy used in the Western world. In Japan this method was invented independently, and the chain of reasoning that led to this result was quite different from that of the European inventors and was based on totally different and very fertile ideas. The description of this development offers most interesting reading and may yield new points of view to workers interested in this field of roentgenology.

The book is written in English. The language is, however, somewhat odd and there are many spelling errors. But in spite of this, it may be recommended because of its original ideas.

Paul Edholm

ANGIOGRAPHIE DER NIEREN. Von Erich Vogel und Rudolf Herbst. 112 S., 97 Abb. Georg Thieme, Stuttgart 1957. DM 54.

The authors discuss the methods of renal angiography by means of the intravenous injection of contrast medium, injection into the aorta directly after percutaneous translumbar puncture, and into the aorta or renal artery after percutaneous transfemoral catheterization. They now prefer the latter methods but note the value of the translumbar intra-aortic injection when catheterization fails; the intravenous injection is rarely used and then in children.

Due consideration is given to earlier papers on various techniques, complications of the different methods, and renal damage due to the injection of the contrast medium. The anatomical variations of the arteries are considered. The normal angionephrographic effect of the kidneys is described as the sum of the contrast-filled vessels and capillaries in the organ — a too simple single explanation of the phenomenon. The different pathologic findings which follow are presented in a lucid manner. The authors emphasize the importance of angiography in diagnosing phaeochromocytoma but of the three vascular sources of the suprarenal glands those from the inferior phrenic arteries are not mentioned.

The illustrations, with the exception of those of some of the angionephrograms, are in most cases very good. There are only in a few cases references in the text to the figures; however, these may be understood with the help of the clear legends. In many of the illustrations urography or pyelography is added for comparison with the angiographic findings but it is remarkable to a Scandinavian radiologist how often pyelography (this by catheterization) is performed instead of urography.

The monograph ends with a bibliography containing references to most of the authors who have dealt with the subject.

N. P. G. Edling

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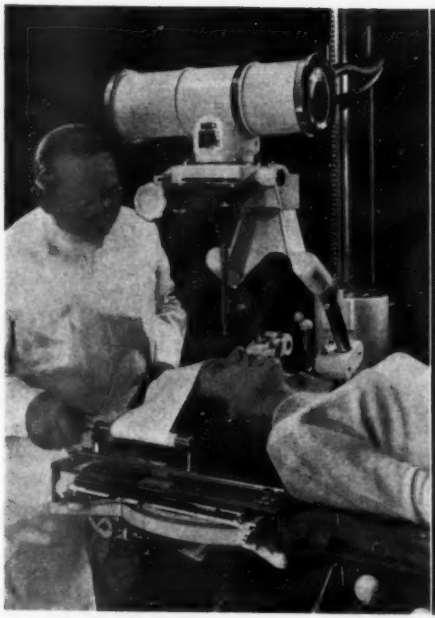

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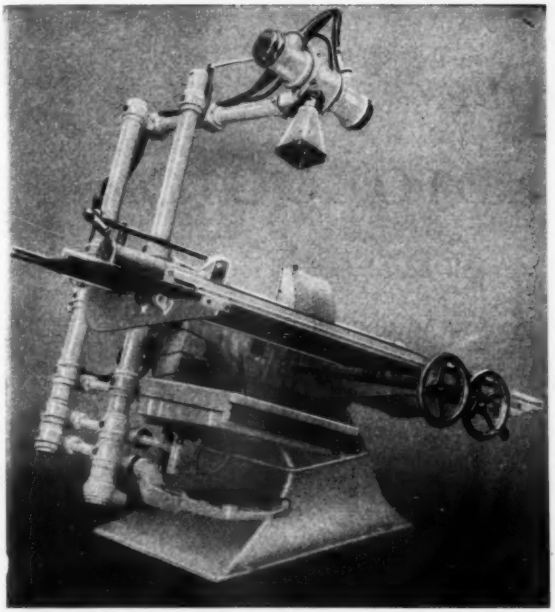

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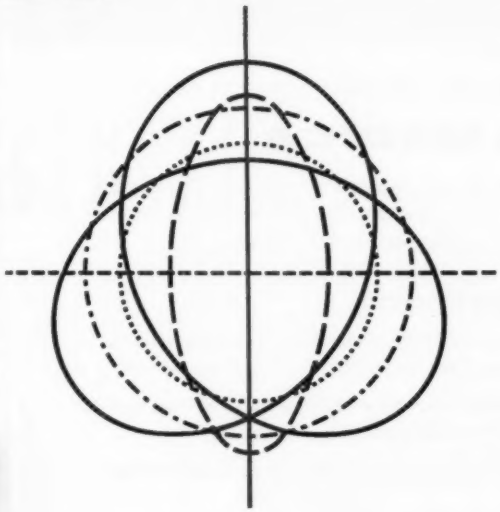

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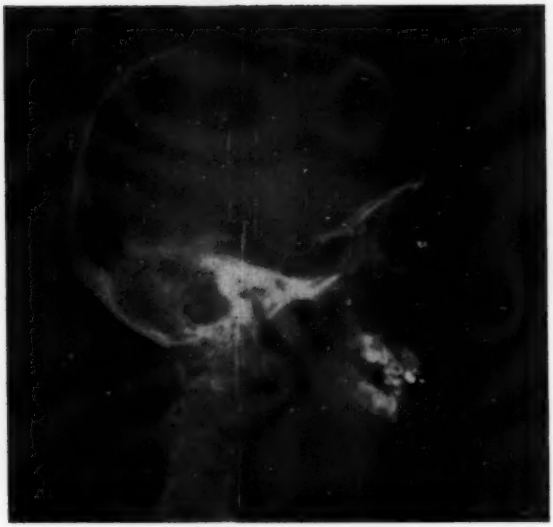

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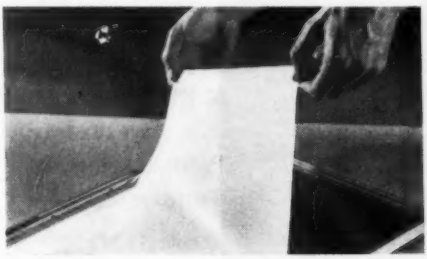

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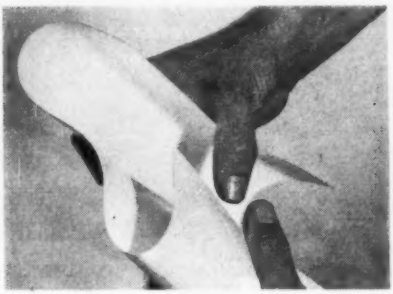

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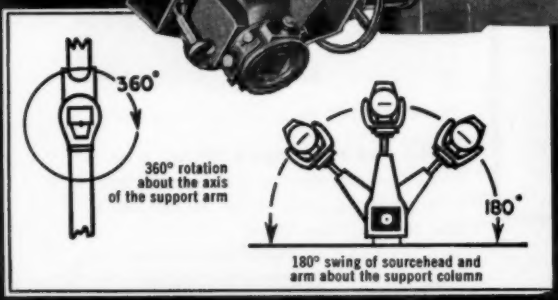

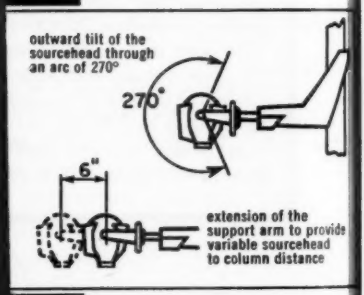
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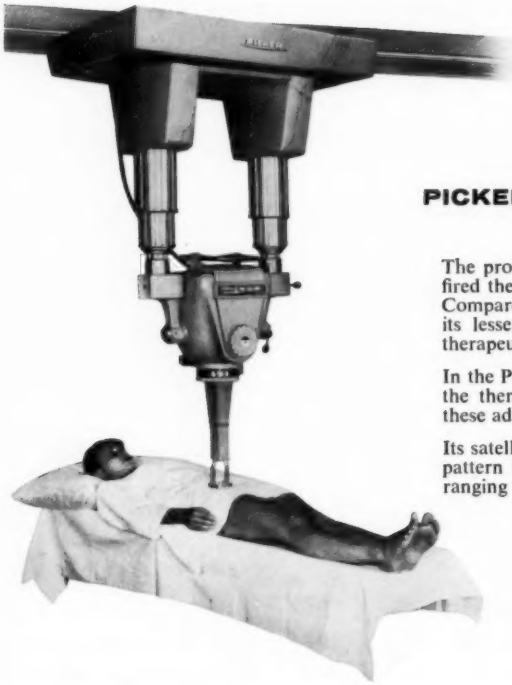

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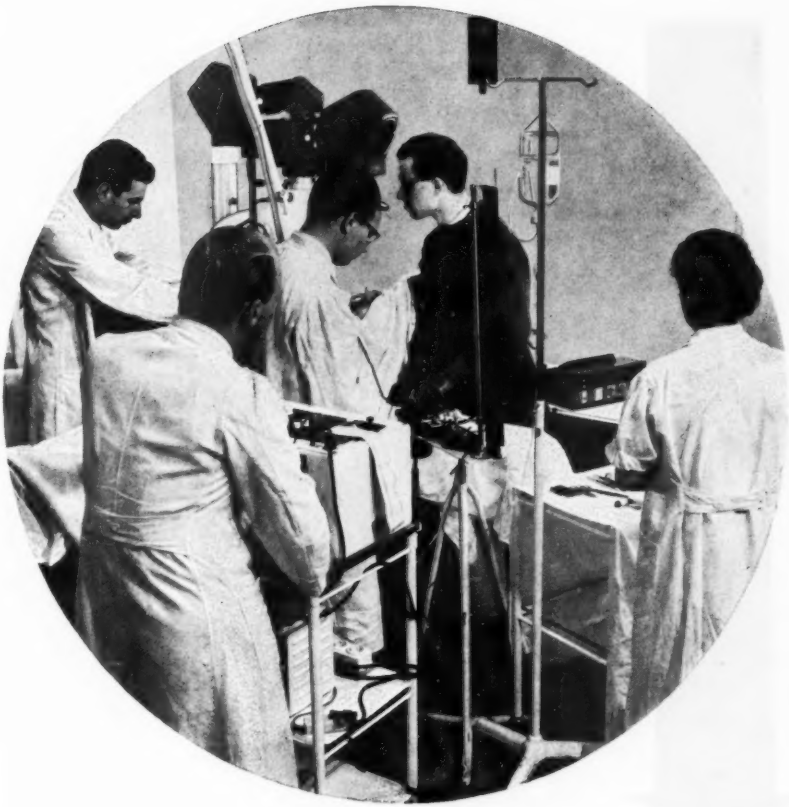
PICKER CARDIOLOGICAL X-RAY UNIT

A single comprehensive apparatus with which you can . . .

Fluoroscope on an 8″ amplifier tube • Monitor continuously on closed-circuit TV • Record an examination on 16mm cinefilm • Fluoroscope in the large on a non-amplified 12″ x 12″ fluoroscope screen • Get a 10″ x 12″ radiograph anytime during the examination.

See a "live" demonstration at our Stand No. 97. —Since this unit will be energized you will be able to view the image on the TV monitor screen.



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9-inch Image Intensifier used in heart catheterization.

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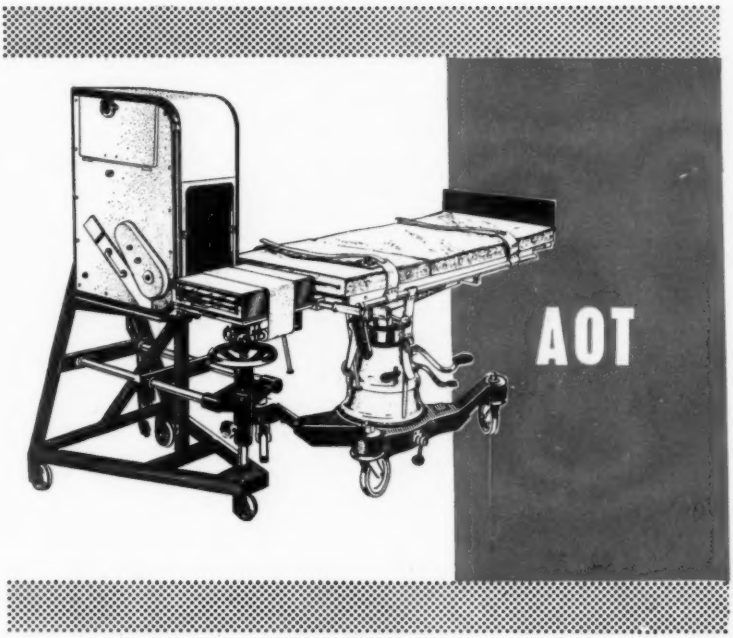

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